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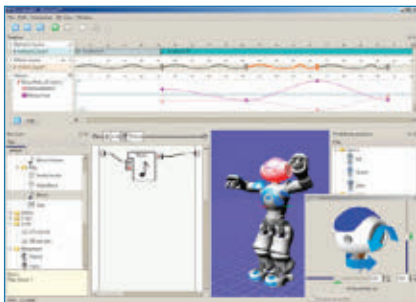
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Voice Memo
Alarm Clock**

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■ By Dave Decker

●●●● Advanced Level

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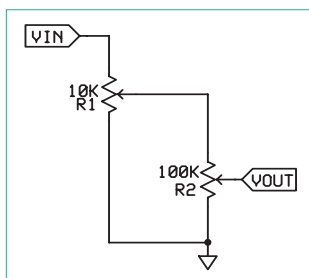
■ By Fernando Garcia

●●●● Advanced Level

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Even in the midst of the digital revolution, there's still a place for analog mathematics to streamline your designs.

■ By Gerard Fonte



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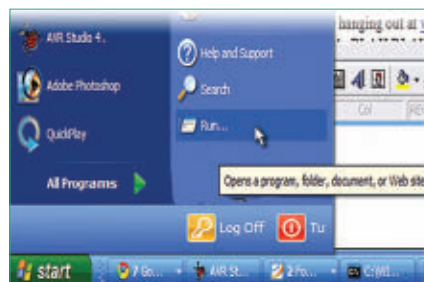
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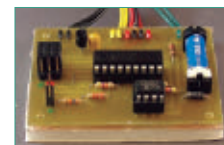
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And now, a riff from Jim Beck ... designing a wireless guitar system.

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Final Frontier*

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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

MIDI INTEGRATION

If you're a regular reader of this column, you know of my affinity for working at the system integration level as opposed to low level circuit design. I see it as a natural

progression of anyone involved in electronics. After you've built a solid foundation of principles and components, the challenge naturally migrates to applying your understanding of circuitry to some practical task.

My latest integration project is building MIDI controllers in the form of electric guitars. Although the Musical Instrument Digital Interface (MIDI) standard has been around for years, only recently have affordable MIDI drivers and matching synthesizers for guitars been available. The project in the **accompanying photo** is that of an electronic Fender Telecaster which I built using a MIDI interface board from Roland Corporation. The black MIDI pickup sensor is visible in the photo, just beyond and parallel to the magnetic pickup.

When I plug the guitar into an audio amp, it sounds like an ordinary Telecaster — perhaps with a bit more resonance, in part because of the cavities drilled through the body for the MIDI electronics and cables. However, when I plug the guitar into my Roland guitar synthesizer, I can play percussion or wind instruments, or anything in between.

Unlike a traditional magnetic pickup — which combines the signals generated by the six magnets and wire coils interacting with the six steel strings — each string has a separate pickup for MIDI. As a result, you have much more control over how signals are mixed and sounds are ultimately synthesized. Of course, it takes much more to make music than being able to pluck a virtual note on a harp or harpsichord, but it's a start for someone with a modest music background.

If you're thinking of exploring the world of modern MIDI controllers and guitar synthesizers, I wouldn't suggest taking a router to your favorite guitar, especially if you're unfamiliar with working with guitar bodies. Instead, start with a relic guitar or start from scratch; amazing second-hand components are available on eBay. I chose the latter route and picked up a

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used Fender body, neck, tuners, pickup, and other components at a considerable discount. It's a simple enough project and there are numerous websites on DIY guitar topics, from how to set intonation to the various ways to wire the magnetic pickups. Other than the strings, the only item I purchased new was the Roland GK-Kit-GT3 GR-Synth Driver. This MIDI driver is available online from a variety of vendors, including **MUSIC123.com** and **GuitarCenter.com**.

To build my MIDI guitar, I took the blank body and wrapped it in newspaper to protect the finish. Then, with a hand router, I made space for the two pushbuttons and switch for controlling the remote synthesizer, as well as the MIDI board and the special 13-pin connector on the edge of the guitar. Fortunately, the connector supplies power to the guitar — otherwise, I would have had to route out a cavity for the battery. I used a milling machine to remove a strip of the pickguard, making room for the electronic pickup sensor. In all, I removed about nine ounces of wood — enough to change the resonance of the guitar body compared with my other, non-modified Telecaster bodies. One of the challenges in working with electronic musical instruments is that you can get the electronics 100% correct and end up with a lousy sounding instrument. Fortunately, the slightly increased bass sustain that resulted from hollowing out space for components was a welcome change.

If you're hesitant to take a power tool to your polished guitar body, you can purchase a clamp-on MIDI interface. However, I haven't had much luck with these, especially on guitars with a metal plate surrounding the rear pickup, such as a traditional Telecaster. There is also the issue of the cable placement and I found the device simply interfered with my playing. The internal interface, in comparison, isn't noticeable. Simply plug in the 13-pin cable and start playing, similar to the operation of the standard audio jack.

If you're not into electric or electronic guitars, there are other options for controlling MIDI synthesizers, including MIDI wind instruments, such as the wireless MIDI wind controllers from Yamaha. However, these instruments and associated electronics are much more delicate than a set of strings attached to a slab of swamp ash or mahogany. Regardless of controller, once you have a means of generating specific MIDI data, you've opened up a new world of exploration.

Do you have a MIDI project that you'd like to share with other readers? If so, please consider sending in your story and a few photos of your work. **NV**



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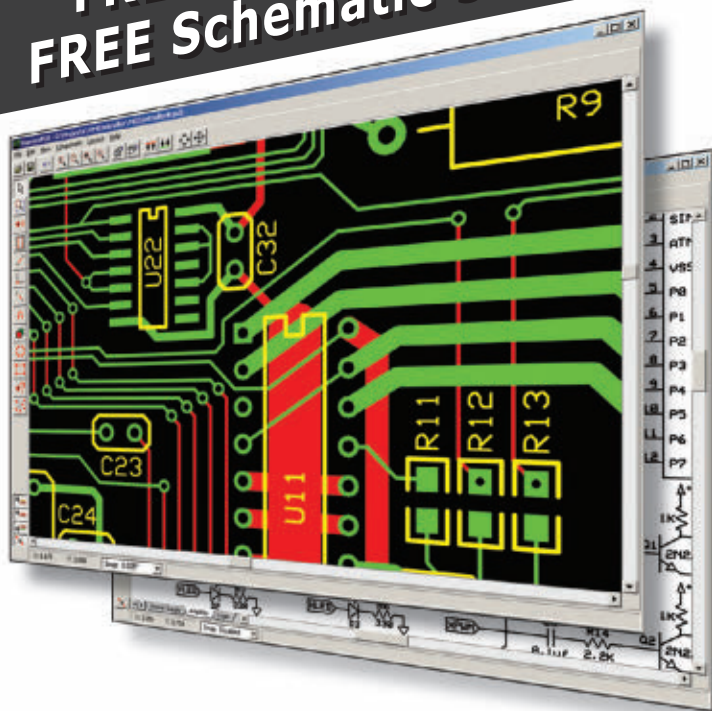


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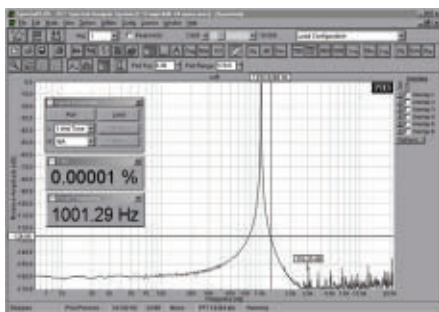
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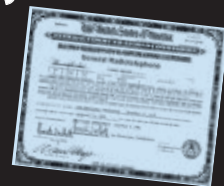
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■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

MATERIAL SPEEDS UP CHARGE/DISCHARGE



■ Sample of a new material for improved Li-ion batteries.

It is, of course, annoying that lithium-ion batteries take hours to charge up, but until recently that was believed to be an inherent quality of the battery material. Lithium-ions simply move very slowly through the substance, making charge and discharge times agonizingly slow. But a few years ago, engineers at MIT (www.mit.edu) ran some computer calculations involving lithium iron phosphate (a common battery material), resulting in predictions that the ions actually should be pretty swift little critters. They've been looking into the anomaly and recently discovered that the ionic movement can be sped up considerably if we channel the particles into the material through tunnels on its surface, rather than just letting them meander around on their own. Team leader Gerbrand Ceder likens it to how beltways in large cities efficiently channel traffic, thus also proving that he has never driven a car into Washington, DC. The engineers have now created a small battery that can be charged or discharged in 10 to 20 seconds rather than the six minutes it takes with the standard material. Because

this material is not entirely new, the concept may find itself in commercial use within two or three years in the form of smaller, lighter, and overall better batteries for cell phones, laptops, and other devices. Ceder has speculated that it could be scaled up to be applicable to electric cars, but with some limits — trying to charge your car's batteries that quickly could provide something of a challenge to your home circuit breaker box.

NO MORE WAITING FOR THE BUS

A working bus of the future appears to have arrived courtesy of Automotive OEM Daimler AG (www.daimler.com). Scheduled for a formal premiere in June at the Vienna UITP World Congress and Mobility & City Transport Exhibition, the Mercedes-Benz Citaro FuelCELL Hybrid Bus is the brand's first fuel cell hybrid bus and the latest in a line of vehicles aimed at achieving zero emissions. It all began in 1997 with the NEBUS research vehicle, leading to a diesel-electric hybrid, and now to the 2009 model which has dropped the diesel power plant in favor of hydrogen cells that charge the lithium-ion battery pack. Thus, the vehicle is exhaust-free and nearly silent in city driving. It is driven by four hub motors that also act as generators when the driver steps on

■ Artist's conception of the Citaro FuelCELL bus.



■ The Itronix GD6000.

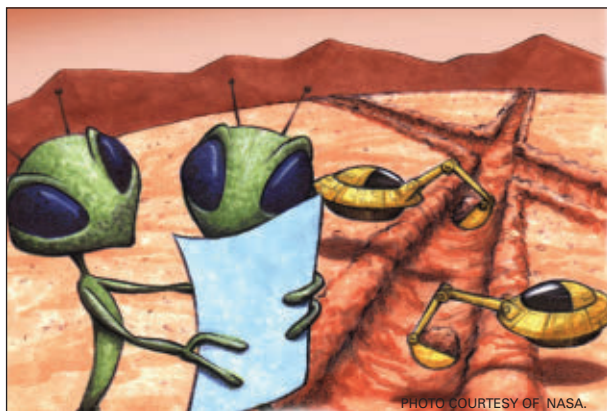
the brake, boosting efficiency.

One question left unanswered by the company, though, is how much it will cost to acquire and maintain a fleet of them. Although 36 fuel cell buses have been tested between 2003 and 2006, that's not a large base for predicting how horrific the price might be on such a relatively low-volume vehicle. But, hey, the more you spend, the more you stimulate the economy, so why sweat the details?

COMPUTERS AND NETWORKING

NEW VEHICLE-RUGGED NOTEBOOK

With the Christmas season well behind us, few new consumer-oriented PCs are arriving on the market. But for field technicians, police, and anyone who bumps around all day in a truck, patrol car, or van, there is the GD6000 vehicle-rugged notebook from General Dynamics Itronix (www.gd-itronix.com). Based on the Itronix GBook®VR-2, the GD6000 is the company's next generation of rugged notebook, designed especially for a mobile workforce. It meets their very specific requirements for durability and superior performance, while



■ Martian canal builders.

supporting increasingly complex applications.

Specifically, what you get is a machine that meets MIL-STD 810F standards (see www.dtc.army.mil/navigator) for temperature range, vibration resistance, and dust and humidity protection. It comes with a 13.3-inch DynaVue® touch screen display (designed to give clear images in anything from low light conditions to streaming sunlight), a 2.53 GHz Intel Core 2 Duo T9400 processor, a 120 GB drive, and up to 4 GB of DDR3. You also get GPS and wireless connectivity with Wi-Fi, WWAN, and Bluetooth. The unit weighs in at 6.2 lb and is EnergyStar® and Electronic Product Environmental Assessment Tool (EPEAT) certified at level “silver.” (For details, see www.epeat.net.)

Best of all, it says “General Dynamics” in big letters on the case, so people will think you are a big shot with the military or CIA. All this comes at a price, though, which at press time was about \$3,500 to \$4,200 on various Internet sites.

EARTH TO MARS

In case you haven’t noticed, Google Earth is no longer a terrestrial-only explorer, as version 5.0 can fly you to Mars and provide 3D mapping there, as well. In March, Google announced some additional features. First, you now can take a historical tack by viewing maps made by early astronomers such as Schiaparelli and Lowell. Then, jump to the present day with the “Live from Mars” layer, which feeds you a stream of imagery

from current spacecraft, including images from a camera aboard NASA’s Mars Odyssey. You can also tag along with the Mars Reconnaissance Orbiter and see what it’s been up to. Plus, two guided tours are available, narrated by Ira Flatwo (of NPR’s Science Friday) and Bill Nye the Science Guy.

If you don’t have version 5 yet, just go to earth.google.com for the free download. (Be careful, though, because the Martians may be monitoring your computer’s activity, and they’re not known to appreciate peeping Toms. If they detect you, they may stop by in the middle of the night and eat your liver.)

IF YOU DON’T WANT TO CRASH AND BURN ...

According to a recent security bulletin, a critical vulnerability has been found in Acrobat Reader 9 and earlier versions, as well as Acrobat 9 Standard, Pro, and Pro Extended. The little bug can cause the application to crash and allow an attacker to take control of your system, which can be a little annoying.

If you use any of these products, it is highly recommended that you proceed to www.adobe.com/support/security/bulletins/apsb09-03.html and download the appropriate update. Windows and Mac versions are currently available, and the Unix patch should be there by the time you read this.

CIRCUITS AND DEVICES

30% BOOST WITH NEW DSP

On the component level, the new TMS320C6457 digital signal processor (DSP) from Texas Instruments (www.ti.com) should be of interest in networking, military, imaging, and industrial markets for

applications such as medical imaging, radar, industrial vision systems, and test equipment. It’s available at operating speeds of 1.2 and 1 GHz, and is said to deliver up to 30 percent more performance at two-thirds the cost of current TI single-core DSP processors.

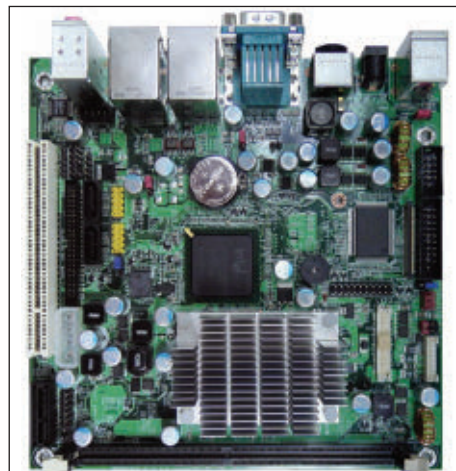
Key features cited include 9,600 (16-bit) MMACS of peak performance enabled by 2 MB of on-chip L2 memory (up to 1 MB cacheable), faster 32-bit DDR2 EMIF (667 MHz), plus memory, cache, and bus architecture enhancements; available high speed interconnects (SRIO and SERDES interfaces); and on-chip acceleration for telecommunications applications. The 1.2 GHz version runs \$146; the 1 GHz runs \$112, in 1,000 unit volumes.

YOUR NEW MOTHER

On the board level, a new entry is the ITOX (www.itox.com) NP101-D16C Mini-ITX motherboard, intended for cost-sensitive applied computing and x86 embedded systems applications including medical electronics, industrial control, security/surveillance, telecommunications, ATM/POS, digital signage, gaming, and kiosk systems. It employs a 45 nm 1.6 GHz Intel® Atom™ N270 processor with the Intel® 945GSE Express chipset and an ICH7M I/O controller hub.

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INDUSTRY AND THE PROFESSION

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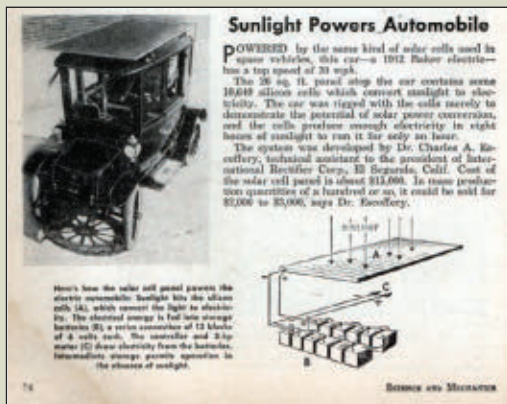
Reflecting the overall economic gloom, National Semiconductor recently reported Q3 2008 sales of \$292 million, down 31% from Q2 of the same year and down 36% from Q3 of 2008. As a result, the company will reduce expenses by eliminating 850 positions immediately and perhaps as many as 875 more over the next few quarters while consolidating its manufacturing facilities. The company will close its assembly and test plant in Suzhou, China, and its wafer fabrication plant in Arlington, TX. National currently employs

about 6,500 people worldwide, so these actions will result in the elimination of 26% of the company's workforce.

SOLAR CARS HIT 50

With all the current research and improvements in the field of solar powered cars, it's easy to forget that the idea is anything but new. In fact, it was 50 years ago in 1959, when International Rectifier (www.irf.com) built a solar cell array and mounted it atop a 1912 Baker Electric. On March 16, 1960, it debuted as the world's first solar powered car on the TV show "I've Got a Secret." The 26 sq ft panel contained 10,640 cells and produced 200W. An eight hour

charge would provide only one hour of operation, so it was produced only for demonstration purposes. If you want to see a fully restored 1912 Baker, just drop by the lobby of HEXFET America in Temecula, CA.



15W, it provides higher per-watt performance than previous mobile platforms. A single 12 VDC power input further reduces overall system configuration and operating costs. Samples are available now, but price info is available only if you reveal

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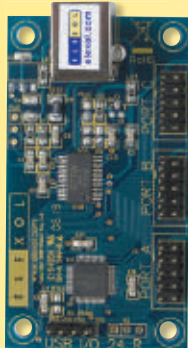
Not everyone will proudly say, "Mine is the world's smallest,"

but Apple is pleased to describe the latest iPod® shuffle in those terms. Not only is the new one half the size of the previous model, its new VoiceOver feature speaks song titles, artists, and playlist names in 14 languages. The third-generation player is smaller than an AA battery, which given that you probably don't have the fingers of a pygmy marmoset, required all of the controls to be located on the earphone cord. The 4 GB memory will hold up to 1,000 tunes based on four minutes per song and 128 kbps AAC encoding. In 256 kbps format, you obviously get half as many. It comes in silver or black, and features a built-in stainless steel clip. At a suggested retail price of \$79, am I finally going to buy one? Nah. **NV**

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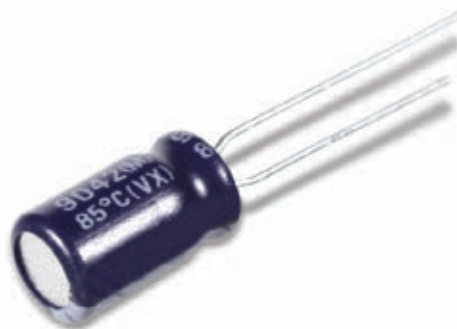
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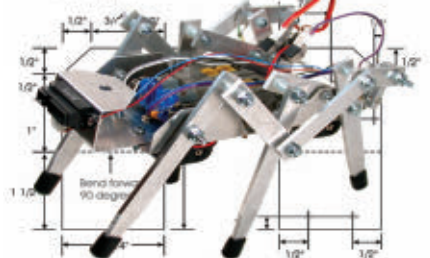


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PERSONAL ROBOTICS

UNDERSTANDING, DESIGNING & CONSTRUCTING ROBOTS & ROBOTIC SYSTEMS

■ BY VERN GRANER

THE SAGA OF THE SONAR STATION

THE SONAR STATION IS AN INTERACTIVE KIOSK that entices visitors to experiment with, play with, and learn about sonar distance measurement. Using a combination of robotic, acoustic, and visual devices, the kiosk responds to visitor's motions with fun and entertaining real-time reactions.



PLAY IT BY EAR

When the Austin Children's Museum was gearing up to host the Bay Area Discovery Museum's "Play It By Ear" exhibit (see Resources), they decided it would be neat to add some Texas flair. They set aside some funds and drafted a "Call To Artists" announcement which was sent to various art groups in the city. As The Robot Group has been a consistent supporter and contributor to Austin Children's Museum events, it wasn't long before the announcement popped up on The Robot Group mailing list and I immediately started drafting ideas on how we might be able to participate.

After reading the announcement, my original thought was to re-package the popular Theringing instruments that create music by detecting the player's hand position over a sonar sensor (see the complete writeup in

the April 2006 issue of *Nuts & Volts*). The Theringings had been well received every time we brought them out to museum events but they are designed to be held by the "musicians" and, if operated by visitors, they require a "conductor" to supervise the operation.

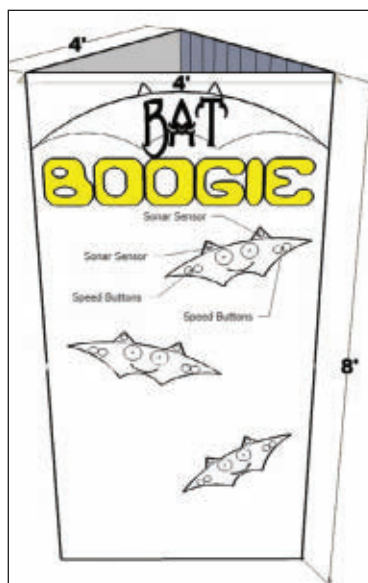
The trick would be to integrate the instrument's functions into a kiosk style device that would eliminate the need for visitors to wear the instrument and also eliminate the

need for a conductor. In addition, we wanted to find a fun and educational tie-in for sonar range finding and the city of Austin. The obvious answer was ... bats.

THE BAT BOOGIE

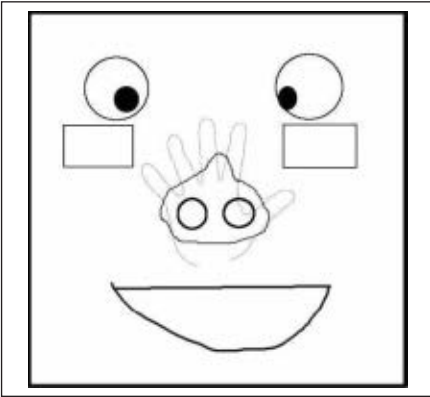
The Congress Avenue Bridge in downtown Austin, TX is home to the largest urban colony of Mexican free-tail bats in North America (the colony is estimated at 1.5 million!).

The Congress Bridge bats are a well-known city attraction, so I decided to base the theme of the kiosk on a mixture of the Theringing instruments and the sonar echo-location capabilities of bats. I made some pencil drawings of the concept piece (**Figure 1**) which I then visualized in Google Sketchup (**Figure 2**). I wrote up a comprehensive proposal with my renderings and the proposed kiosk's capabilities which I



■ **FIGURE 1.** First concept sketch of the Bat Boogie kiosk.

■ **FIGURE 2.** Google Sketchup version of the Bat Boogie kiosk.



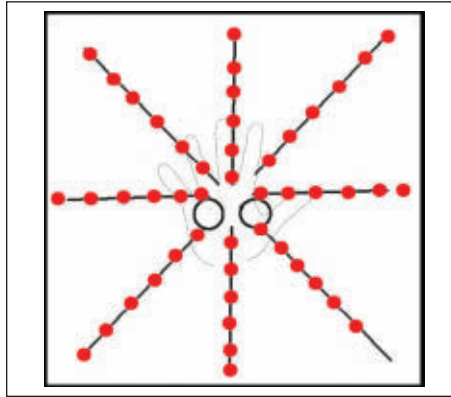
■ FIGURE 3. The FACE window concept sketch.

sent off to The Children's Museum. Before long, I received a response from the Exhibit Director. My proposal was approved!

ITS PERFECT! BUT, CAN WE CHANGE ... EVERYTHING?

With the proposal accepted and the funding allocated, all we needed to do was have a small meeting with The Powers That Be at the museum to work out the "details" of the project. At the meeting, the museum folks let me know that, though they loved the proposal, they would like to make some small changes.

For starters, they didn't want the kiosk to use bats in its design theme. Secondly, they wanted the unit to be mostly transparent so the visitors could see the inner workings. And lastly, they wanted the unit to operate without playing music. At first I thought they were kidding. Turns out they weren't (uh oh).

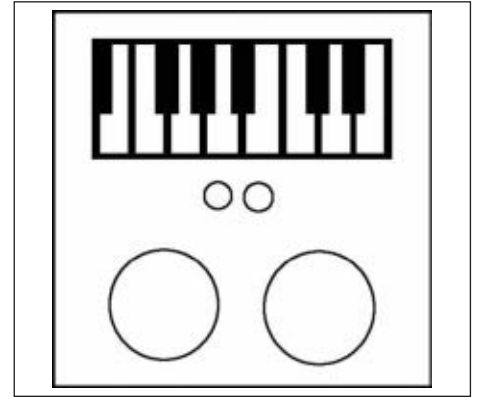


■ FIGURE 4. The STAR window concept sketch.

Of course, this was all presented in a very positive way. In fact, I could take it as a compliment of sorts that they believed I was creative enough to take my gutted project and resurrect it into what they envisioned. But, no matter how I looked at it, it simply meant a lot more thinking, designing, and work.

BACK TO THE DRAWING BOARD

I spent the next few days banishing the bats and banning the "boogie" from all the designs. I decided to focus on making a kiosk where visitors could simply interact with sonar ranging in a real-time, visceral way. I settled on three different interactive experiences that would be solid examples of sonar ranging. In my new design, the three-sided kiosk would have three separate clear plastic "windows" that would each reveal the components inside. In my new sketches, I named the windows "FACE," "STAR," and



■ FIGURE 5. The PIANO window concept sketch.

"PIANO," and they worked like this:

FACE WINDOW

The FACE window (Figure 3) used a robotic positioning system that moved servo motors in proportion to values received from the sonar sensor. A pair of ping-pong ball "eyes" would appear to follow the visitor's hand as they moved it closer and farther away from the sonar sensor "nose" in the window. The eyes in the window would eventually cross in a fun and silly manner when you had your hand right up against the nose.

STAR WINDOW

The STAR window (Figure 4) was designed to provide a very visual display of sonar ranging. This window would be filled with concentric rings of colored LEDs in a circular shape. As a visitor would bring their hand closer to the center of the circle, more sets of lights would activate, creating a moving, colorful star burst that expands and contracts in relation to the distance of the

■ FIGURE 6. Bruce Tabor marking up the panels for the kiosk.



■ FIGURE 7. Cutting the window holes in the kiosk panels.



■ FIGURE 8. Window holes cut and routed in the kiosk panels.

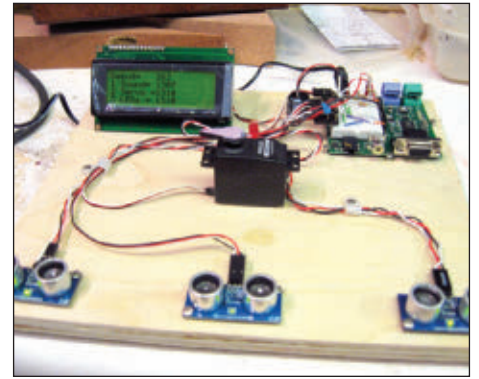




■ FIGURE 9. Mike Scioli test fits the top plate on the kiosk.



■ FIGURE 10. Paul Atkinson assembling the "back boxes" for each kiosk panel.



■ FIGURE 11. The Propeller Demo Board prototyping platform.

hand from the sonar sensor.

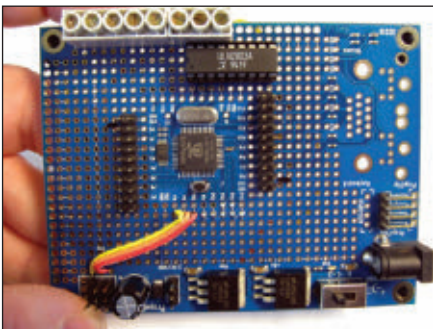
PIANO WINDOW

The PIANO window (Figure 5) would provide an audible response to the sonar range readings. A drawing of a piano keyboard would be placed behind the window and LEDs placed behind each piano "key" to indicate what note is being played. A speaker would be mounted in the middle of the window so the visitor could hear the notes as they play. Bringing a hand close to the display would cause the piano to play notes that increase in pitch, and lower pitches would play as the hand moved away.

THINKING OUTSIDE THE BOX

Once I had the three windows defined, I decided I would keep some of my original design criteria such as placing three windows per panel and having each window at a different level to accommodate different viewing heights (children/adults/wheel chairs). The windows would be placed in an offset configuration to

■ FIGURE 12. The Propeller Proto Board after circuit transfer.



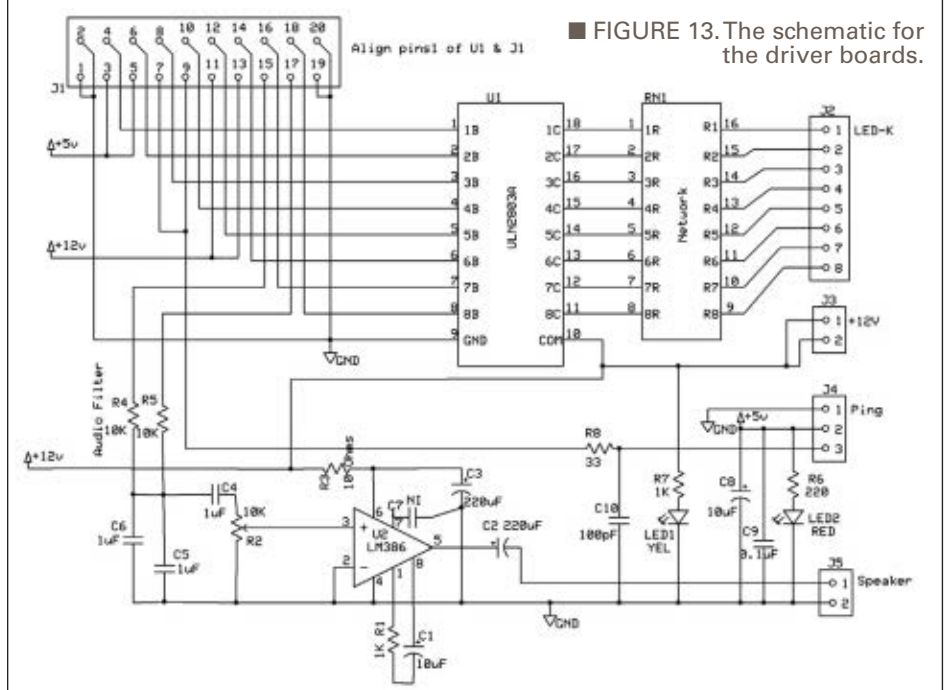
accommodate multiple visitors at once. For example, a parent could interact with the top window while a small child could stand in front of the parent and play with the bottom window. The middle window would be off-set to the side to allow someone to stand next to the parent/child and easily interact with the middle window. To make each window type accessible to all three height levels, they would rotate positions on each panel. For example, Panel 1 would have the Star in the top location; Panel 2 would have the Star in the middle; and Panel 3 would have the Star on the bottom. A person of any height would only need to walk around the kiosk to experience all of the different window types at the

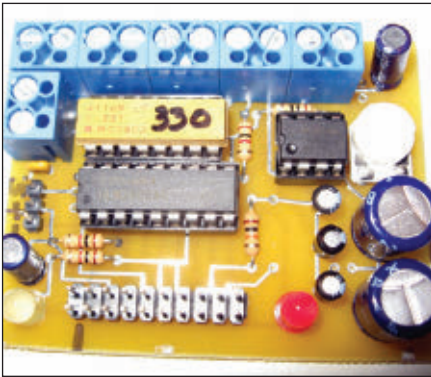
height they prefer (or require).

In order to make the unit function no matter the lighting level of the venue, I planned to install CCFT lights in each window that could be switched on and off by the micro-controller. This would allow the visitor to see the inner workings of the machine even in low-light situations. As I worked on the design, I sent progress updates to the museum folks to make sure we stayed on the same page. After a few weeks, we settled on a design we could all agree upon. It was time to get busy and build it.

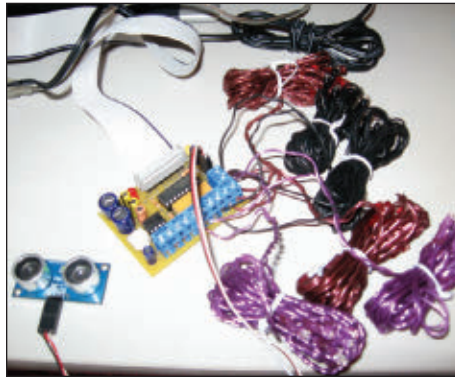
LETS MAKE SOME SAWDUST

The final design called for a three-





■ FIGURE 15. The PCB fully populated.



■ FIGURE 16. The PCB with lights and sensor connected and working.



■ FIGURE 17. The Parallax Sonar Sensor mounted behind the plastic window.

sided kiosk with three windows in each panel. This design would be flexible in that the three panels could be arranged in a triangle for a stand-alone display, or the panels could be placed in a row flat against a wall to take up a minimum amount of space. With rough-sketched plans in hand, I went to visit (and frustrate the heck out of) my good friend Bruce Tabor. Bruce is an experienced professional carpenter with a well-stocked shop. As he is used to building precision crafted pieces, my hand-cobbled drawings that were devoid of reasonable scale or sane measurements caused him no end of grief.

In spite of my 50% burro plans, Bruce got right to work making the panels. In seemingly no time, he had all three panels marked (Figure 6), cut to size (Figure 7), and routed for the windows (Figure 8). I dragged along some of my friendly neighborhood roboteers to help with the sanding, cutting, drilling, and other assembly. While we completed that, Bruce finished up the kiosk top, bottom (Figure 9), and the window backing-boxes (Figure 10). When we were done, I carted everything back home and had my three-sided kiosk standing in the dining room ready to stuff with electronics!

SPINNING UP A SOLUTION

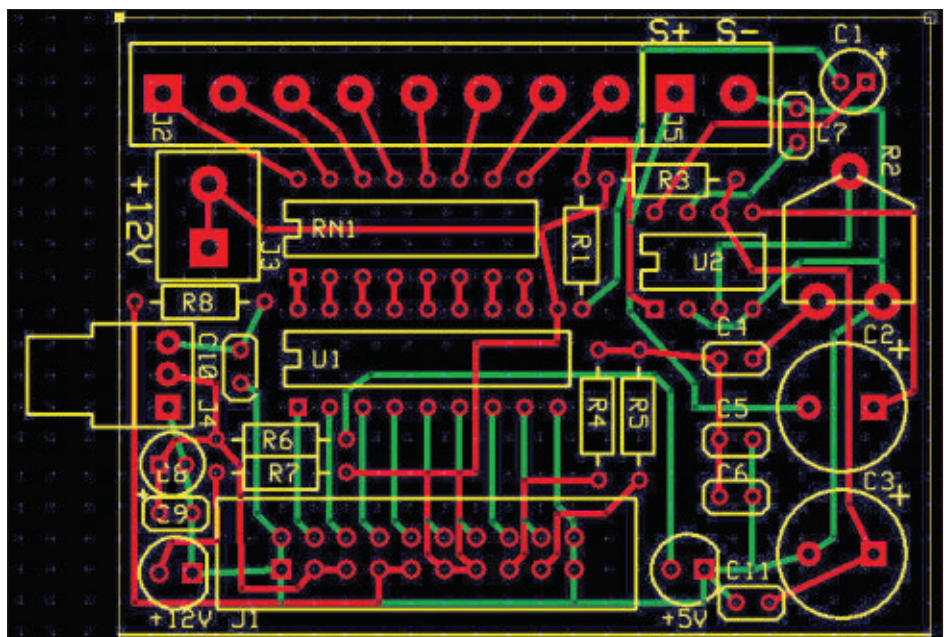
The Propeller chip from Parallax has some amazing capabilities and I

had been looking for a project where I could experiment with this powerful, new multi-core microcontroller. The Sonar Station seemed to be the ideal candidate. Though I hadn't had any experience coding in the SPIN language, I had done quite a bit of programming in PBASIC on the BASIC Stamp series of microprocessors from Parallax. With a background in PBASIC, the SPIN language is surprisingly simple to understand. In addition, I had the good fortune of knowing some local "Propeller heads" that could help me if I got stuck. As luck would have it, one of the foremost experts on the Propeller, André LaMothe (see Resources) had recently moved to Austin! Not only had he come out to some Robot Group meetings, but when I told him about this project, he graciously

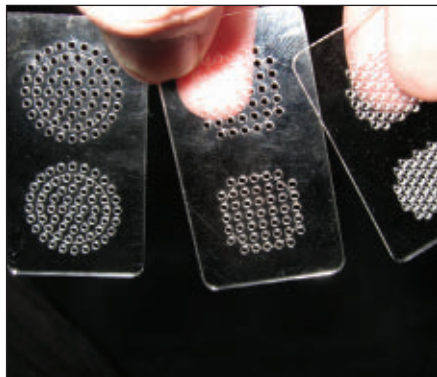
offered to assist with the design and troubleshooting of the code.

PROPELLER PROTOTYPE

To get started, I created a board that I could use to test and prototype the software (Figure 11). In previous projects where I had time-sensitive peripherals to control, I would normally have mounted a dedicated servo controller or other "helper" hardware on this test board. This is because with a single microcontroller dealing with more than one time-sensitive device, you would have to code very carefully to insure you service all time-sensitive devices. For example, if a single microprocessor is waiting for a sonar sensor to return a pulse from a distance measurement, the microcontroller is "blocked" from



■ FIGURE 14. The PCB layout for the driver boards.



■ FIGURE 18. Various sonar sensor test bezels.

doing anything else until that measurement is complete. If during this blocked time the servo motor needs a pulse to update its position, the single microcontroller cannot perform this task and so the servo is liable to move erratically. Typically, a serial servo controller of some type would be employed to provide consistent pulses to the servo motors and to make programming less critical. Unfortunately, this additional hardware adds cost.

With the Propeller chip and its multiple "cogs," I effectively had eight separate microcontrollers I could use at the same time. The SPIN language allowed me to assign tasks to each cog such as controlling a servo motor or fetching a sonar distance measurement. I used the freely available "objects" from the Parallax website (see Resources) to do both of these tasks without having to spend additional money on external helper hardware. I effectively replaced hardware with software for free.

ONE THING LEADS TO ANOTHER

Once I had the Propeller Demo Board prototype up and running, I turned again to Paul Atkinson for his help in creating the schematics and printed circuit boards (PCB). Paul started by porting the design from the original Propeller Demo Board over to the Propeller Proto Board (Figure 12). He then used free software from ExpressPCB (see Resources) to whip up a schematic that would include a small audio amp for the PIANO window, a ULN2803a driver for the



■ FIGURE 19. The three panels set up together.

strings of LEDs in the STAR window, a header for the servo in the FACE window, and connectors for the 12 volt CCFT lights (Figure 13).

He then laid out a PCB (Figure 14) and we sent the board off to ExpressPCB to have it made. When the finished boards arrived, Paul was able to populate them (Figure 15) and test them with all components mounted and working (Figure 16). If you ever are planning to build a project of this scope, my advice to you is to make friends with a professional electrical engineer!

WINDOWS FOR WOOD WALLS

As Paul was busy soldering up the PCBs, I called on my old friend Rick Abbot to help me with the creation of the actual clear plastic windows. Rick started by fabricating an aluminum template so he could cut each window to size and to position identical holes on each panel. Then, using a two-step drilling process, he crafted special holes to hold the sonar sensors in place while shielding the delicate front screen of the sensor from direct exposure to the kiosk visitors (Figure 17). Lastly, he drilled the holes for the speaker in the PIANO window and the pattern of holes in the STAR window.

I did a press-fit of the LEDs for the star to see how it would look and was very impressed with how well the plastic panels carried the lights. So, with the custom PCBs completed without a failure, the cabinet built without a hitch, and all the windows



■ FIGURE 20. A custom laser-cut sign to top off the Sonar Station.

fabricated and ready to mount, it was obviously past the time for something to go wrong.

THE PATH TO SUCCESS IS PAVED WITH PERSISTENCE

The first indication we had of a problem came when we noticed that when mounted in the window, one of the sonar sensors was no longer responding. As we had nine different panels and we had been inserting and removing sonar sensors quite often, we assumed we had damaged a sensor. I replaced it and the window began to work. Then, in a bit, we notice another one of the windows ceased to work. We soon discovered that all the sonar sensors would work intermittently when they were inserted into the mounting holes in the windows!

For those of you who enjoy drama, chaos, and panic, feel free to visit the Parallax forum thread mentioned in the Resources section. There you can follow along as I frantically searched for help in discovering how much of the front of the sensor could be obscured, how resonance of mounting material might affect the sonar distance readings, the effect alternate grill materials would have on the sensor readings, and the like. For those who just want to know how it all turned out, this is what happened: After swapping sensors, trying different grill materials, and even testing precision laser cut bezels with different patterns and densities

from my buddy Ed Gonzalez at Oak Hill Laser (**Figure 18**), in the end we discovered that by simply "angling" the sensor very slightly in its mounting hole, it would work reliably.

Our guess is that the sensor was picking up reflections from the flat material between the exit holes. We noted that the sensor front and the grill surface of the window were in parallel with each other creating a resonant chamber. In the finished windows, I would turn the unit on, insert the sensor into the mount, then angle it slightly until it would start to work. Once in the "sweet spot," I fixed the sensor in place with a blob of hot melt glue. Problem solved.

ATTRACT MODE?

Now that we finally had the basic functions up and running, it was time to tweak the software a bit to make the display more eye-catching. I wanted the display to entice people to interact with it. As designed, when the display was waiting for someone to use it, it was fairly static. There was no motion, no flashing lights, nothing that might draw you to see what the kiosk was all about. I decided to take a cue from video arcade game designers of yester-year and add an "attract" mode to each panel.

The idea was to keep track of the time that has elapsed since the last interaction with any of the windows and, if that time went beyond a certain threshold (30 seconds or so), the unit would do things to attract attention. With some programming help from fellow roboteer Gray Mack

we settled on an attract mode that would exhibit the following behaviors:

- The CCFT back lights for each window sequence on and off to create an interesting light and dark pattern.
- The "eyes" in the FACE window periodically track together looking left and right as if watching for the next visitor to approach.
- The LED lights in the keyboard of the PIANO window would sequence up and down, casting interesting shadows from the interior wiring.
- The LED lights in the STAR windows sequence back and forth creating growing and shrinking concentric rings that are compelling to watch.

I toyed with the idea of having the unit emit sounds during the attract mode, but ultimately decided against it as I didn't want to annoy the exhibit staff who may be stationed nearby for extended periods of time.

Once we had the three panels assembled and programmed, I set them side by side back in the dining room (**Figure 19**) and let them lapse into Attract mode. I turned the lights off and the light show was dazzling! NOTE: If you would like to see a video of the Sonar Station panels in action, check out the video link in the Resources section.

GOOD THINGS COME TO THOSE WHO WAIT

Though we now had a fully-functioning Sonar Station, we were sadly way past our delivery date.

Between all the painstaking hand-construction and the hard stop we hit when we couldn't get the sonar sensors to reliably operate, the Premiere of the Play It By Ear exhibit had come and gone. Lucky for me, the good folks at the Children's Museum we both patient and kind. They listened to the stories of sensor failure and other issues and only offered support and encouragement. They even offered to extend our run at the museum and welcomed us without question when the project was finally finished.

The night before we were due to deliver the unit, Ed Gonzalez came by to drop off the finishing touch. Laser cut from clear acrylic panels, emblazoned with the kiosk name in hot-red letters and pre-drilled with holes for a string of RGB color-changing LEDs, this three-sided custom crafted sign gave the unit a distinctive professional look (**Figure 20**). We were finally ready to deliver this baby!

SETUP IT UP!

In the early hours of a Saturday morning, Paul Atkinson, Ed Gonzalez, and I loaded the Sonar Station into Ed's truck and headed downtown to The Children's Museum. We had a slim installation window as the Museum was scheduled to open at 10:00 A.M. We had to have it assembled, installed, tested, and all our tools cleaned up and out no later than 9:55. The Museum's Technical Director, Chris Brown, met us at the door and helped us unload (**Figure 21**) and assemble the panels (**Figure 22**). It took only two hours to get power run

■ FIGURE 21. Vern Graner assembling the Sonar Station.



■ FIGURE 22. Paul Atkinson and Ed Gonzalez putting the top on the Sonar Station.



■ FIGURE 23. Children's Museum visitors interact with the Sonar Station minutes after its installation.



and to get everything together. At 9:50 A.M. that morning, the Sonar Station was live!

AND NOW, THE REST OF THE STORY

As we were packing up and talking to the museum folks, parents and children had already started to interact with the machine (**Figure 23**). The Sonar Station ran all that day and continued to run without failure for the remainder of the Play It By Ear exhibit. It continued on to be featured at The Children's Museum for a number of weeks even after the show had closed. Comments from the visitors were very positive and the machine only experienced a single failure just before it was retired from the floor. Seems a rather enthusiastic child hammered his fist on one of the lower windows until the hot melt glue came loose and the sonar sensor fell out of place (a few drops of hot glue brought the unit back online).

All in all, I feel the project was an unmitigated success and I expect to place the machine in other locations around Austin and the Central Texas area in the future. In the meantime, it's a pretty neat dining room ornament. :) As always, if you have any questions please feel free to contact me at vern@txis.com. **NV**

Credit Where Credit is Due

I'd like to thank Erich Rose, Becky Jones, and Chris Brown with the Austin Children's Museum for making the Sonar Station a reality. I'd also like to thank The Robot Group and all the members of the Sonar Station team:

Andre LaMothe: Propeller SPIN code programming
Gray Mack: Propeller SPIN programming
Paul Atkinson: PCB design and layout, cabinet assembly and installation
Bruce Tabor: Lead Carpenter and cabinet design
Mike Scioli: Cabinet assembly and finishing
Edward Xavier Gonzalez: Laser cut plastics, cabinet assembly, delivery, and installation
Rick Abbott: Plastic window fabrication & bracket machining
Kym Graner: Planning and logistics

Thanks everyone! It wouldn't have been possible without you!

RESOURCES

■ Bay Area Discovery Museum
 "Play It By Ear" exhibit
www.baykidsmuseum.org/tour_the_museum/special_exhibitions/play_it_by_ear/

■ The Austin Childrens Museum
 Press Release
www.austinkids.org/About-Us/Newsroom/-Play-It-By-Ear.aspx

■ The Robot Group
www.TheRobotGroup.org

■ The Therepings
www.thereping.com

■ Google Sketchup
<http://sketchup.google.com>

■ André LaMothe
http://en.wikipedia.org/wiki/Andre_Lamothe

■ Parallax Object Exchange
<http://obex.parallax.com>

■ ExpressPCB
www.expresspcb.com

■ Sonar Sensor discussion on Parallax forums
<http://forums.parallax.com/forums/default.aspx?f=10&m=256496>

■ Video of the Sonar Station in Action
www.youtube.com/VernGraner

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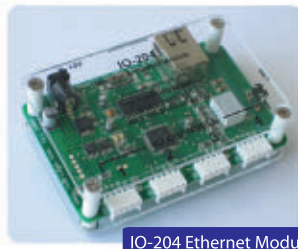


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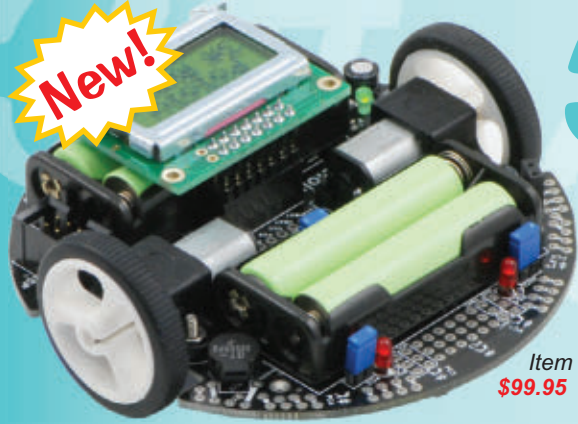


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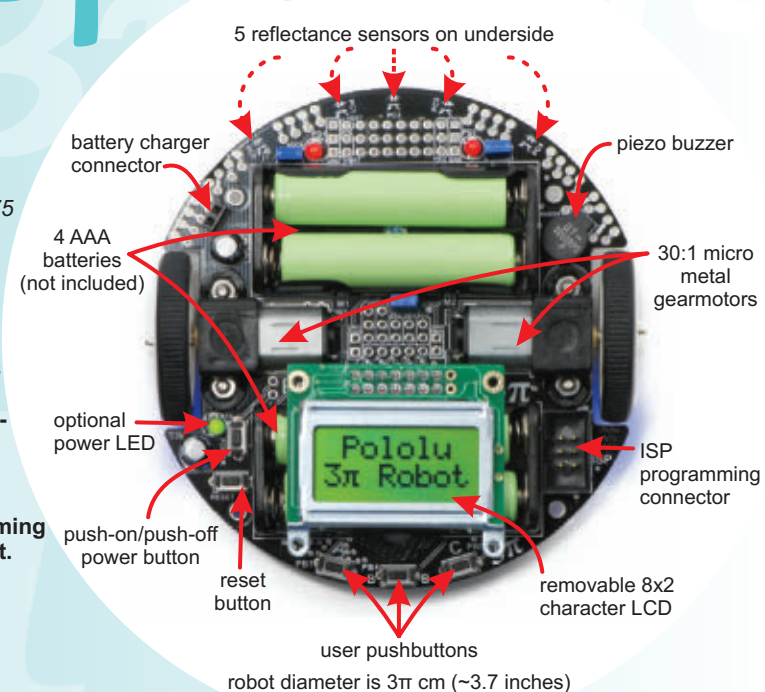
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Super Hi-Q ferrite rod antenna with Faraday shield eliminates noise from power lines, dimmers, static and more! Great results from 500kHz to 15MHz. Super for AM broadcast band! Includes power supply.



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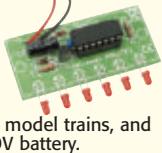


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This little kit flashes six high intensity LEDs sequentially in order. Just like the K80302 to the right does with incandescent lights. Makes a great mini attention getter for signs, model trains, and even RC cars. Runs on a standard 9V battery.



MK173 Mini LED Light Chaser Kit

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Controls and powers 4 incandescent lights so they appear to "travel" back and forth (Like the hood on KITTY)! Great for the dance floor or promotional material attention getters, exhibits, or shows. Runs on 112-240VAC.

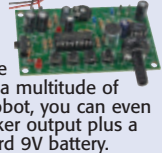


K8032 4-Channel Running Light Kit

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This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even ad vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.



MK171 Voice Changer Kit

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High power LED's have finally found their way into the hobbyist budget, but now you need a driver! This little board provides the accurate and constant current need to drive them. Delivers 350mA or 700mA at a constant current

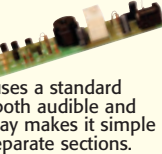


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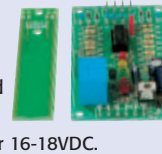


LTS1 Laser Trip Sensor Alarm Kit

\$29.95

Liquid Level Controller

Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.



K2639 Liquid Level Controller Kit

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MC1 Mini Electret Condenser Mic Kit

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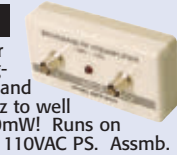


RF1 Sniff-It RF Detector Probe Kit

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Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.



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Mad Blaster Warble Alarm

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MB1 Mad Blaster Warble Alarm Kit \$9.95

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MK108 Water Sensor Alarm Kit \$6.95

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Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.



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SBRGB1 SMT Multi-Color Blinky Kit \$29.95

Practice Guitar Amp & DI

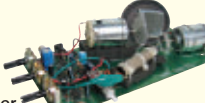
Practice your guitar without driving your family or neighbors nuts! Works with any electric, acoustic-electric, or bass guitar. Plug your MP3 player into the aux input and practice to your favorite music! Drives standard headphones and also works as a great DI!



PGA1 Personal Practice Guitar Amp Kit \$64.95

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Voice Activated Switch

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TS4 Tickle Stick Kit \$12.95

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TD1 Encoder/Decoder Kit \$9.95

Doppler Direction Finder

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DDF1 Doppler Direction Finder Kit \$169.95

Super Snoop Amplifier

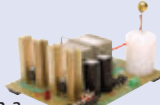
Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watt output drives any speaker for a great sound. Makes a great "big ear" microphone to listen to the "wildlife" both in the field and in the city! Runs on 6-15 VDC.



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COUNTING PULSES WITH TIMER 0

- Readable and writeable as two bytes.
- Can be fed from internal clock or external clock signal

- Can be set to create a hardware interrupt at overflow (65535 > 0)
- Can use a four-bit prescaler, 1:2 to 1:8.

TMR2

- Readable and writeable as one byte
- Writable comparison byte size register
- Only fed from internal clock
- Constantly compared to secondary, preset binary value
- Can have 1:1, 1:4, 1:16 prescaler or 1:1, 1:2, 1:3 to 1:16 postscaler
- Output can drive synchronous port
- Can be set to create a hardware interrupt at match of preset binary value

All three of these timers can be fed from the internal clock, but TMR0 can also be fed from an external input pin. This allows TMR0 to act as an event counter rather than a timer. TMR1 can be controlled by an external crystal separate from the internal clock or from an external input, making it a 16-bit counter. This offers the opportunity to control TMR1 externally from a slower clock source such as a digital watch crystal or a digital counter source.

TMR2 can only run from the internal clock but can be automatically set to constantly check if it matches a preset value similar to a time-elapsed timer. I used Timer2 in the September 2008 column when I showed you how to generate a pulse width modulated (PWM) signal.

Table 1 shows the features of the three timers along with the control bits to set up these features.

Each of the timers has a register where the timer value can be read or written to. The Timer0 register is named TMR0. TMR1, has two registers – TMR1H and TMR1L – the high-byte and low-byte values. When combined, they form a 16 bit word. To access this timer's value, you have to read each register separately and then combine them into a word variable. Timer0 is easier in this regard as you can read the whole value in one operation.

The PICBASIC PRO compiler lets you read and write to these registers directly, as it has already reserved the register names in its structure. For example, to preset TMR0 to 56 so it will overflow on the 200th pulse rather than the 256th pulse, you just add the following statement to your code:

```
TMR0 = 56      ' Preset TMR0 to 56
```

If you run the TMR0 timer in counter mode (like we will do in this

month's project) and you wanted to check its value in your main program loop, you can read it directly and store it in a variable with the following statements:

```
countervalue var byte      ' Define variable
countervalue = TMR0        ' Read TMR0 value
```

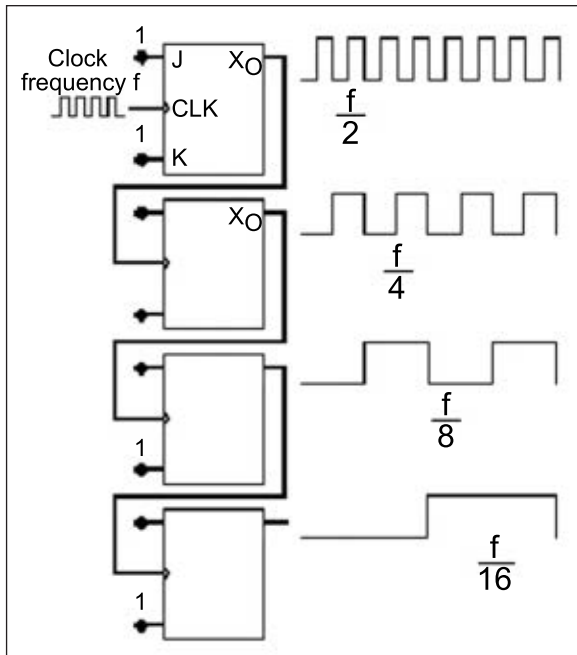
PRESCALER/POSTSCALER

All of the timers have a prescaler or postscaler attached to their input or output. They are pretty much the same thing; one is on the input of the timer (prescaler) and the other is on the output (postscaler). They are just shift registers that have a software-selectable output position. **Figure 2** shows what a section of a prescaler looks like.

Prescalers add a way to slow the clock signal so the counter doesn't overflow or cause an interrupt too quickly. If I have a PIC running with a 16 MHz external resonator, the internal clock feeding the timers would be running at 4 MHz. If you enable the TMR1 prescaler and set it to a 1:4 ratio, the timer clock will slow to 1 MHz

■ TABLE 1. Timer Features.

Features	TMR0	TMR1	TMR2
Size	8-bit	16-bit	8-bit
Prescaler	OPTION_REG.3 - 0 %1xxx = 1:1 %0000 = 1:2 %0001 = 1:4 : %0111 = 1:256	T1CON.5 - T1CON.4 %00 = 1:1 %01 = 1:2 %10 = 1:4 %11 = 1:16	T2CON.1 - T2CON.0 %00 = 1 %01 = 4 %1x = 16
Postscaler	Not Available	Not Available	T2CON.6 - 3 %0000 = 1:1 :%1111 = 1:16
Interrupt-Enable Bit	INTCON.5	PIE1.0 and INTCON.6	PIE1.1 and INTCON.6
Interrupt Flag	INTCON.2	PIR.0	PIR.1
Internal Clock	Fosc/4 Selected by OPTION_REG.5 = 0	Fosc/4 Selected by T1CON.1 = 0	Fosc/4 (Only Option)
External Crystal/Resonator	Not Available	Crystal or Resonator connected between C0 and C1 pins Selected by T1CON.1 = 1 and T1CON.3 = 1 Sync external with internal clock selected by T1CON.2 0 = Synchronize 1 = Do Not Sync	Not Available
Counter Mode or External Clock Mode	Pulse signal connected to TOCKI Pin Selected by OPTION_REG.5 = 1 Edge Select Bit for Incrementing: OPTION_REG.4 0 = Low to High 1 = High to Low	Pulse signal connected to C0 pin Selected by T1CON.1 = 1 and T1CON.3 = 1 Sync external with internal clock selected by T1CON.2 0 = Synchronize 1 = Do Not Sync	Not Available
On/Off Control	Not Available (Always on)	T1CON.0 0 = Off 1 = ON	T2CON.2 0 = Off 1 = ON
Timer Register Name(s)	TMR0	TMR1H - High Byte TMR1L - Low Byte	TMR2



■ FIGURE 2. Prescaler Operation.

while allowing the other timers and main program to still run at a 4 Mhz rate. Timer0 and Timer1 both have a prescaler option but only Timer2 has a postscaler.

TIMER SETUP

All of these options — prescaler, internal or external clock source, rising- or falling-edge transition, or any other option you want to change on the timers — is controlled by a few Special Function Registers (SFRs) within the MCU. Each timer has its own set of registers that control its setup. I can't cover all of them in the space provided here, but I do reference them in Table 1. If you read the PIC16F690 datasheet, check out the OPTION, PIE, PIR, T1CON, T2CON, and INTCON registers to see how these various registers play a role in controlling the timers.

TIMERO PULSE COUNTER

This project demonstrates how to use the eight-bit

■ FIGURE 4. Control Panel, in place of scorecard.



■ FIGURE 3. Intelligent golf pull-cart unit.

wide timer as a pulse counter to record distance traveled. Have you ever wondered how far you walked somewhere? I have wondered this many times when I have gone golfing. I don't exactly hit the ball straight, so I end up zigzagging the course. If I totaled the yardage of the course, I would probably be short the total distance I actually walked. To find out, I decided to add a sensor to the wheel of a golf bag pull-cart to give me a pulse every time the wheel makes one revolution. I measured the circumference of the wheel and it was 30". Therefore, every pulse in Timer0 represents 30". Too bad it wasn't a 36" wheel because that would make measuring yardage very easy.

This project will record the pulses and then calculate how far I have walked. The result will be shown on a serial LCD display, which is easily con-

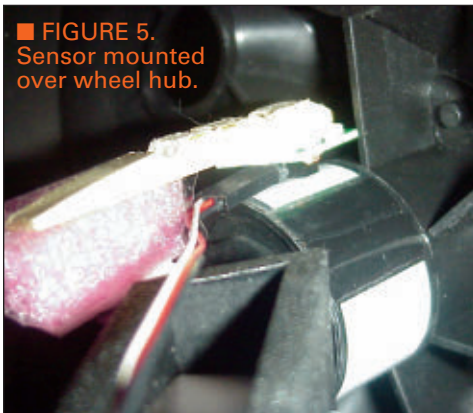
trolled with the SEROUT command line. I want to build this project with the 31 command-limited PICBASIC PRO compiler sample version, so saving space is important. I wanted the hardware to be simple so that I could build this quickly. I decided to use Microchip's PICkit 2 demo board, which I modified with a small breadboard area. This makes the build much faster. The board is powered from a single AA battery using a special 5V adapter from www.bodhilabs.com. This makes it really easy to connect power to the development board without adding a voltage regulator. The finished golf pull-cart unit is shown in **Figure 3**.

The serial LCD, battery pack, and PICkit 2 development board all fit nicely on the area where you would normally put the golf score card. I used double-sided foam tape to hold everything in place. A close-up is shown in **Figure 4**.

The key component is the sensor. Several years ago, I designed a robotic sensor that mounts nicely onto a servo motor. This sensor uses a QRD1114 LED emitter-detector to sense a black and white surface. The output is high or low and requires a simple pull-up on the output. The wheel hub is made of black plastic, so I created a strip

using white paper that covered about 7/8ths of the hub. This left a small black patch that the sensor could detect. Every rotation would create a single pulse because the output would go high when it was over the black and low when it was over the white area.

Figure 5 shows the sensor mounted above the hub with a very crude setup. I plan to make a metal bracket but, in the interest of making my deadline



■ FIGURE 5. Sensor mounted over wheel hub.

for this article, I stuck with my crude mounting to test the system.

TIMERO COUNTER OPERATION

Timer0 is incremented on every falling edge of the sensor signal. Therefore, the accumulated value represents the number of times the cart has moved 30". The software then reads the value of Timer0 and multiplies it by 30 to calculate the total number of inches. From that value, the yardage traveled can be calculated. The calculations and the LCD control software can happen at the same time: Timer0 is a hardware peripheral, so it does its own operation in parallel with the main software running in the program memory.

Timer0 has one register that needs to be set up to work as a counter. That register is OPTION_REG. Each bit has a function, but bits 4 and 5 are the main bits for the counter operation. Bit 5 selects the external A2 pin as the clock source, which is also the TOCKI pin. Then, bit 4 selects the rising or falling edge to increment Timer0.

If you wanted to use the prescaler, you would set that up in this register as well, but I didn't need to. I'll show these bit settings in the software later. This is really all it takes to use the Timer0 as a counter. As mentioned earlier, TMR0 is the actual register that contains the Timer0 value. So in the software, the TMR0 register is read from or written to.

HARDWARE SETUP

The hardware and sensor schematic is shown in **Figure 6**. The connections are simple. The PIC16F690 uses the internal oscillator. The battery supplies the five volts. The serial LCD display uses a board from **www.melabs.com**. The two-row by 40-column LCD display is larger than I needed, but I had it handy.

SOFTWARE

The software listing shown below is really not that long or complicated once you break it down. The software reads the Timer0 value, then calculates and displays the distance on the LCD display. As mentioned previously, I used the PICBASIC PRO sample version for this project. I'll explain the operation in the "How It Works" section.

```
inches var word
decimal var byte
yards var word
```

```
lcd var portb.7

ANSEL = 0           ' Make A2 pin digital
OPTION_REG = %00111000 ' Set Timer0 to count
TMR0 = 0            ' Clear Timer 0
inches = 0          ' Clear inches count
yards = 0           ' Clear yards count
decimal = 0         ' Clear yards decimal value

'****Display Distance on LCD****
SEROUT lcd,6,[$FE,$1,"Total Yards: ",#yards,
".",#decimal]
SEROUT lcd,6,[$FE,$C0,"Total Inches: ",#inches]

'**** Main Loop ****
loop:
  if TMR0 = 0 then loop 'Test for no movement
  inches = (30 * TMR0) + inches 'Total new dist
  TMR0 = 0              'Reset Timer 0
  yards = inches / 36   'Convert to yards

'Calculate decimal value
decimal = (inches//36)*10 / 36

'****Display Distance on LCD****
SEROUT lcd,6,[$FE,$1,"Total Yards: ",#yards,
".",#decimal]
SEROUT lcd,6,[$FE,$C0,"Total Inches: ",#inches]

Pause 1000          'Delay a second between updates
Goto loop
```

HOW IT WORKS

The program starts off by establishing the variables the

REGISTER 5-1: OPTION_REG: OPTION REGISTER

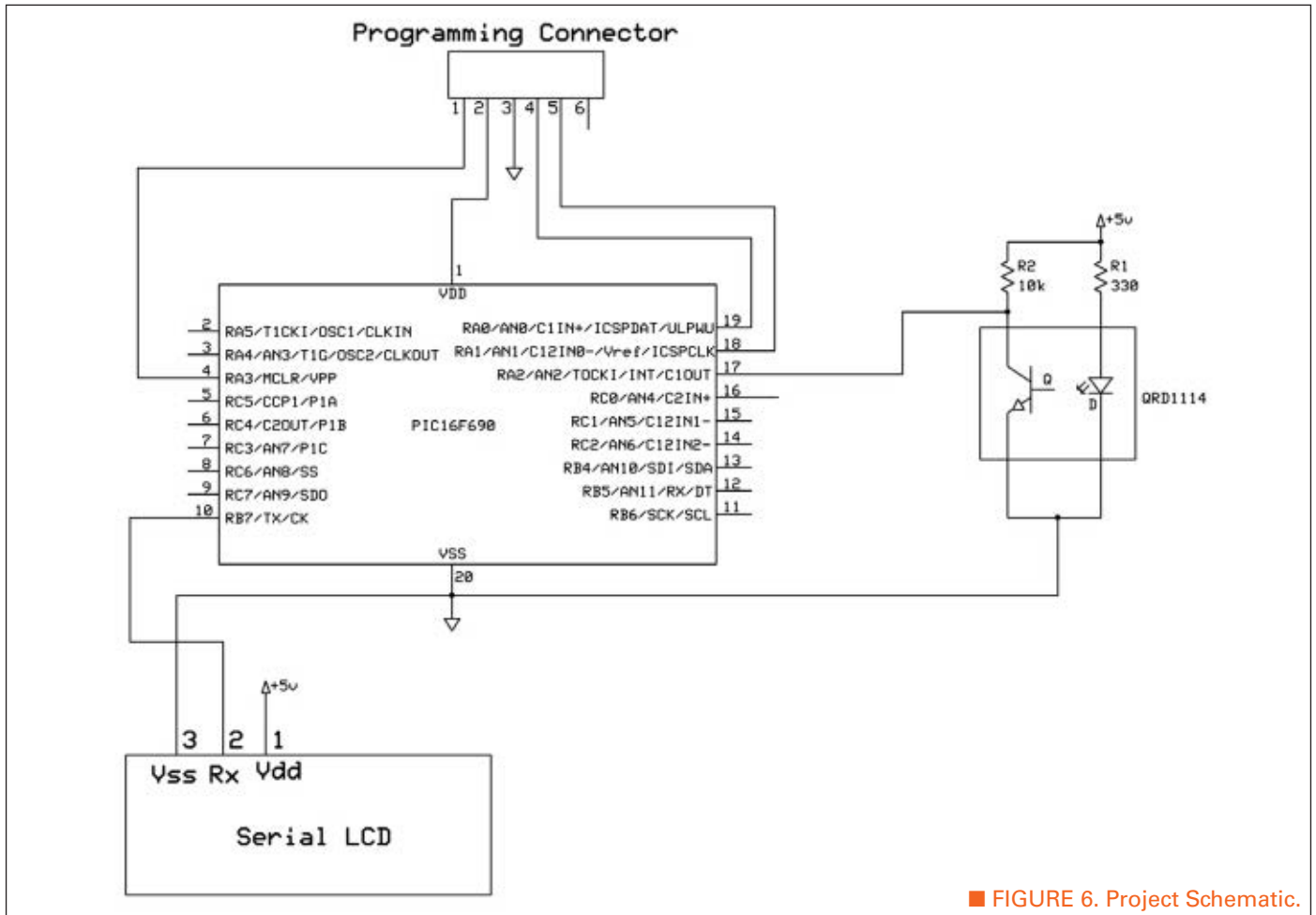
R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
RABPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
bit 7							bit 0

Legend:

R = Readable bit W = Writable bit U = Unimplemented bit, read as '0'
 -n = Value at POR '1' = Bit is set '0' = Bit is cleared x = Bit is unknown

- bit 7 **RABPU**: PORTA/PORTB Pull-up Enable bit
 1 = Pull-ups on PORTA/PORTB are disabled
 0 = Pull-ups on PORTA/PORTB are disabled by individual WPUAx control bits
- bit 6 **INTEDG**: Interrupt Edge Select bit
 1 = Interrupt on rising edge of INT pin
 0 = Interrupt on falling edge of INT pin
- bit 5 **T0CS**: TMR0 Clock Source Select bit
 1 = Transition on TOCKI pin
 0 = Internal instruction cycle clock (Fosc/4)
- bit 4 **T0SE**: TMR0 Source Edge Select bit
 1 = Increment on high-to-low transition on TOCKI pin
 0 = Increment on low-to-high transition on TOCKI pin
- bit 3 **PSA**: Prescaler Assignment bit
 1 = Prescaler is assigned to the WDT
 0 = Prescaler is assigned to the Timer0 module
- bit 2-0 **PS<2:0>**: Prescaler Rate Select bits

BIT VALUE	TMRO RATE	WDT RATE
000	1:2	1:1
001	1:4	1:2
010	1:8	1:4
011	1:16	1:8
100	1:32	1:16
101	1:64	1:32
110	1:128	1:64
111	1:256	1:128

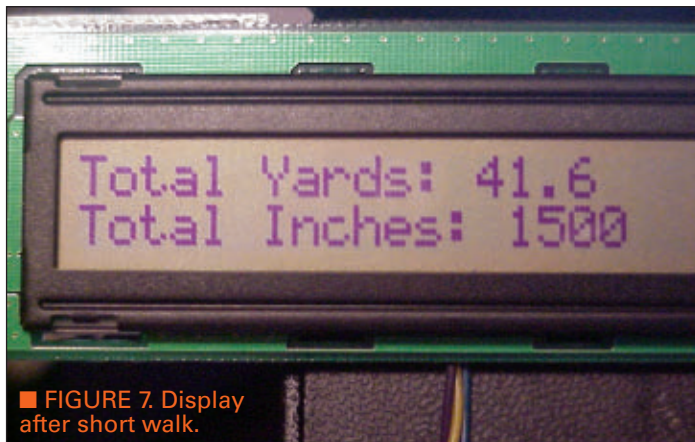


■ FIGURE 6. Project Schematic.

program will use. Some are word variables and some are bytes. I also create a simple nickname for the LCD connection.

```
inches var word
decimal var byte
yards var word
lcd var portb.7
```

The special register setups come next. The TOCKI/A2 pin initializes an analog-to-digital converter (ADC) pin, so I convert it to digital by clearing the ANSEL register.



■ FIGURE 7. Display after short walk.

At first, the program didn't work because Timer0 would not increment. I then realized I had forgotten to clear ANSEL.

The OPTION_REG register establishes Timer0 as a counter. I described earlier how that worked. The settings make Timer0 a counter that increments on the falling edge of the TOCKI/A2 pin. All the variables including the Timer0 value are initially cleared.

```
ANSEL = 0           ` Make A2 pin digital
OPTION_REG = %00111000 ` Set Timer 0 to count
TMR0 = 0            ` Clear Timer 0
inches = 0          ` Clear inches count
yards = 0           ` Clear yards count
decimal = 0         ` Clear yards decimal value
```

The program then displays an initial value on the serial LCD display, which communicates at 9600 baud. The command line positions the cursor at the beginning of line 1 and then displays the "Total Yards" with a decimal point. Then, it moves to the second line with a second SEROUT command and displays the total inches.

```
****Display Distance on LCD****
SEROUT lcd,6,[ $FE,$1,"Total Yards: ",
#yards,".",#decimal]
SEROUT lcd,6,[ $FE,$C0,"Total Inches: ",#inches]
```

The main loop of code begins next. The value of Timer0 is tested to see if it has changed from zero. This indicates whether the cart is moving. If the value of TMR0 is not zero, then the cart is moving so the value of TMR0 is used to calculate the total inches traveled and is stored in the variable inches.

```
loop:
  if TMR0 = 0 then loop  'Test for no movement
  inches = (30 * TMR0) + inches  'Total new dist
```

The value of TMR0 is again cleared since we used its value and it can start counting again as we continue calculating. The value of yards is calculated with simple math and stored in the variable yards. The decimal value for yards is calculated by getting the remainder calculation, multiplying by 10, and then dividing by the value of inches for a yard. The trick is the double slash that gives us only the remainder.

```
TMR0 = 0
'Reset Timer 0
yards = inches / 36  'Convert Distance to yards
decimal = (inches/36)*10 / 36
```

Now that we have the calculations, we can display them on the LCD with the same command lines explained earlier. We then pause for one second and loop back to do it again. During that one second delay, Timer 0 is still collecting pulses as we walk.

```
*****Display Distance on LCD*****
SEROUT lcd,6,[$FE,$1,"Total Yards: ",
#yards,".",#decimal]
SEROUT lcd,6,[$FE,$C0,"Total Inches: ",#inches]

Pause 1000  'Delay a second between updates\
Goto loop
```

The program used 22 lines of code, so it is well within the 31 command line limit of the sample version. You can download the sample version from www.melabs.com.

Figure 7 shows the display after taking a short walk.

The software doesn't include a mechanism to reset the display count back to zero, but the development board has a switch tied to the reset line of the PIC16F690. Therefore, I just pressed the switch to reset everything back to the beginning. An improvement would clearly be to reconfigure the MCLR pin to a digital input and reset the values displayed when the switch is pressed. (I actually showed how to do this in a previous article.) That could be a great next-step project if you decide to build one of these counters for yourself.

CONCLUSION

This project was a lot of fun. I hope you now understand how easy it is to use Timer0 as a counter. The limit of this program is the distance. The inches variable stops at 65,535, because it is a word variable. That equates to 1,820 yards. If you walked a typical, complete golf course, you would travel 7,200 yards or more.

Some modification will be required to create a larger variable size by using two variables — one upper-word size and one lower-word size. Linking these together by creating an overflow from the lower word to the upper word creates a larger variable. I may cover this in a future column, but I'll have to play around with it first. The PICBASIC PRO compiler offers a 32-bit "LONG" variable type, but this is only available on PIC18F applications. You can read more about this in the PICBASIC PRO compiler manual. I also need to improve the sensor bracket and create some kind of cover for the electronics on the golf pull-cart, in case it rains. There are a lot of improvements that can be made, but this is a great starting point.

If you have any questions, comments, or suggestions for project ideas, pass them on to me at chuck@elprod.ucts.com. I'm also working on improving my website with more information for my readers. Look for those improvements soon at www.elproducts.com. I'm moving to a new server to give me more space and more options. See you next time in the July edition of *Nuts & Volts*. **NV**

Chuck Hellebuyck has worked in the electronics industry for over 25 years, holds three US Patents, and has published four books on embedded electronics. He is a Field Applications Engineer with Microchip Technology.

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Analog Tachometer
- ✓ Calculated Inductance
- ✓ Soft Start AC Circuits

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:

Q&A@nutsvolts.com

SPECTRUM ANALYZER SCHEMATIC

Q I have been reading your column and I'd like to ask if you have a schematic or can come up with a relative easy setup that uses readily available ICs for a spectrum analyzer main board; one that will tune from about 1–500 MHz; something that has audio tap and frequency tap (for display, I prefer LED) that can drive most scopes. As an avid amateur radio operator, that is

something I'd like to have in my shack test bench! I've found that most manufacturers don't want to give out schematics and they are fairly costly also. A nice homemade unit which is then serviceable by us hams and affordable would be a nice homebrew addition to our test gear. I hope you can help me out on this. Many thanks!

— Michael Shelton KE4LGX

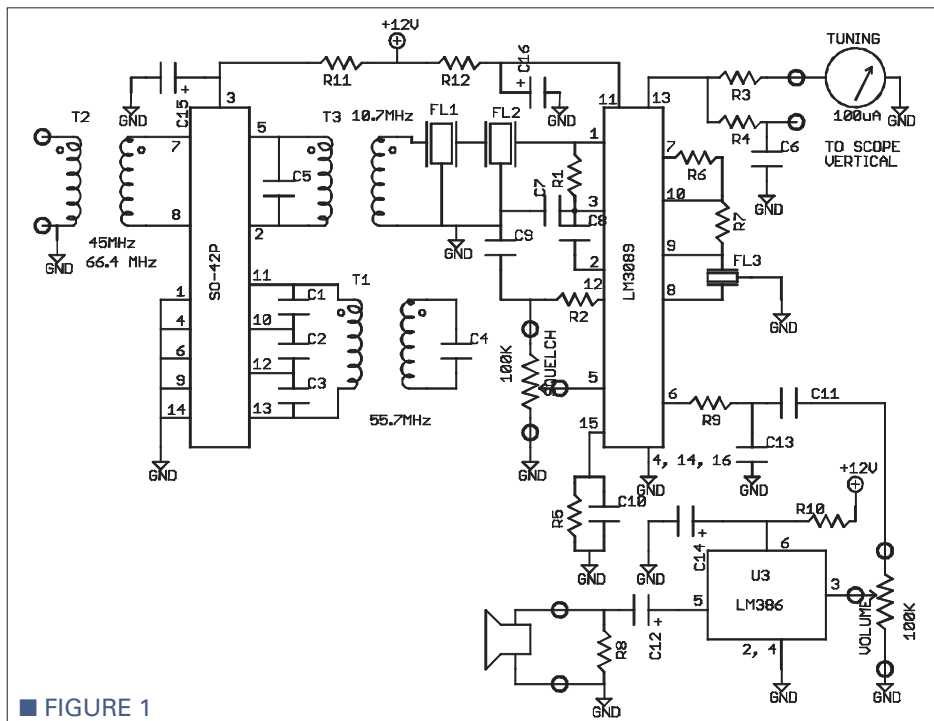
A My first reaction was, I don't have a clue how to answer this question, but in researching on the www, I

found Bruce Barlowe's site www.science-workshop.com/. He has a simple spectrum analyzer main board that is available as a kit. The schematic is **Figure 1**.

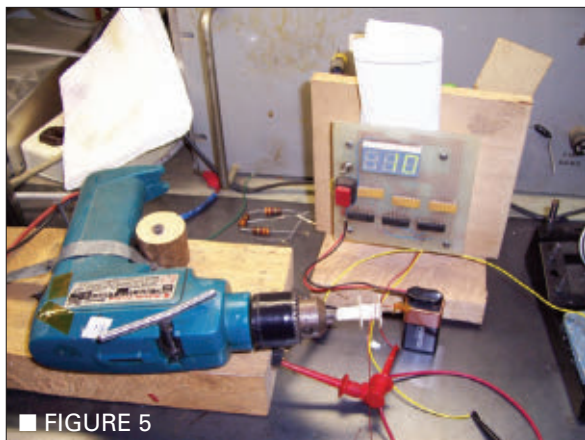
The SO-42P is a VHF mixer rated to 200 MHz, but no doubt has usable response above that. The SO-42P is similar to the MC1496 which could be adapted to this application. The LM3089 is a 10.7 MHz IF amplifier, and with three filters it should have quite narrow bandwidth. Narrow bandwidth is important because this is the filter that selects the frequency to be displayed on the scope. The mixer in this application should be the double balanced type so that neither the local oscillator nor the RF input is passed on to the second mixer.

The mixer output (IF) always contains the sum of the RF and Local Oscillator (LO) frequencies and the difference of the RF and LO frequencies. The system must have a filter at the mixer output to select either the sum or difference unless the frequencies are limited such that either the sum or difference is out of the range of the circuits following.

Another site that is a gold mine of information is www.scottyspectrumanalyzer.com/. If you just want to know more about handling surface-mount devices, it is worth a look. Scotty's block diagram (partial) is **Figure 2**. I like this one because the 1,013 MHz bandpass filter is effective in



■ FIGURE 1



■ FIGURE 5

555 circuit (Figure 3). In the schematic, the LM392 is an op-amp/comparator combination used to amplify and sharpen the pulse. CII differentiates the pulse to produce a short trigger pulse. The pulse width is

linear function of frequency up to 100% duty cycle. I did that because the LM2907 wants a square wave but the magnets on the drive shaft produce pulses. The magnets were 1/8 inch cube super magnets, epoxy-

about 700 μ s, determined by R6 and C6. The maximum frequency is therefore 1.4 kHz. The lowest frequency is expected to be 50 Hz, so the low pass filter is designed to be well below that.

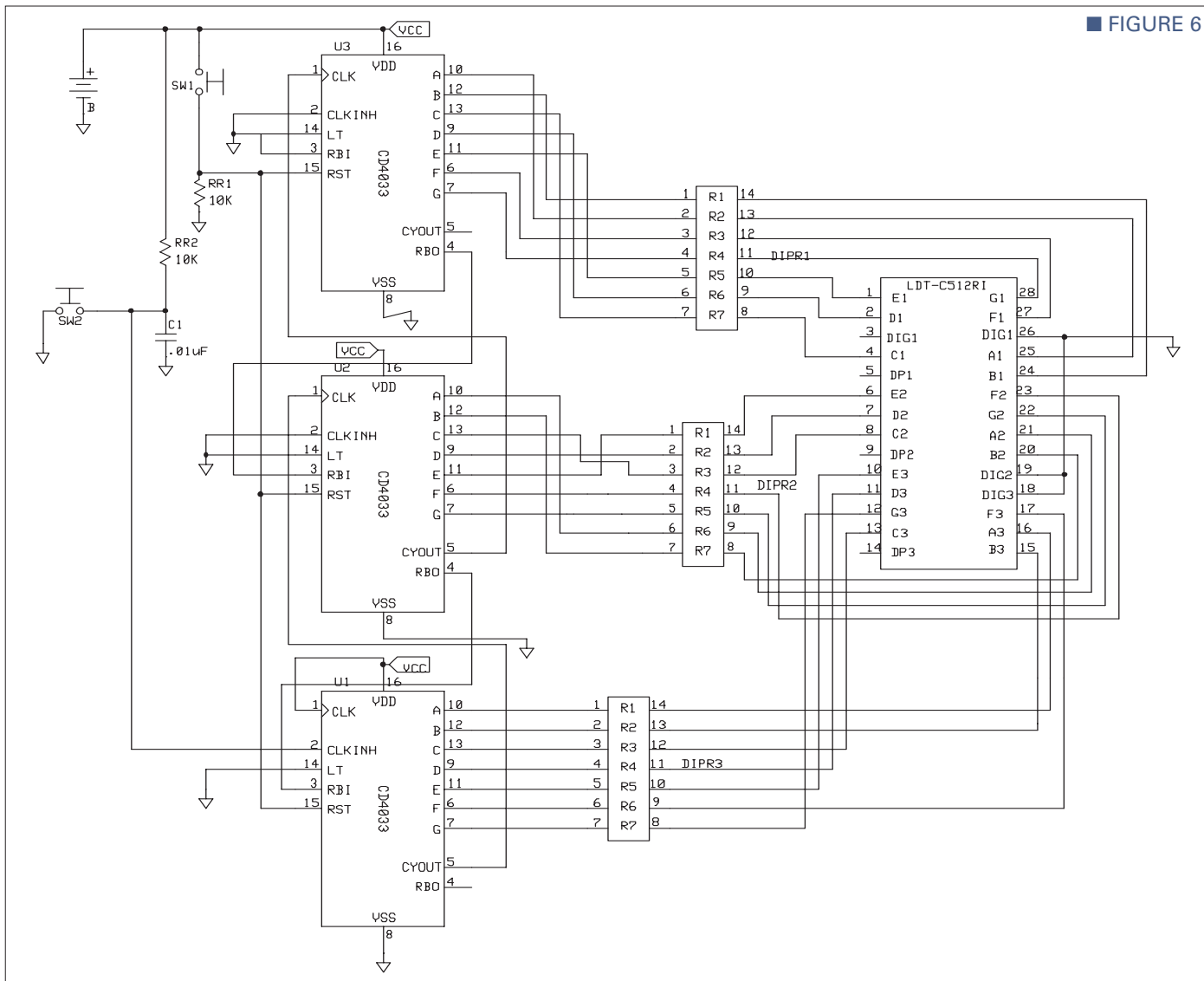
My calculations are Figure 4, from which you can calculate the parameters for your own tachometer. Because the 555 has a constant pulse width, the output is a

glued to the shaft. The layout was designed to mount on the back of the meter (Simpson 260, 50 μ A).

CALCULATED INDUCTANCE

Q I need to know how to rewind some old coils to operate on 200 kHz or 175 kHz. The tuning capacitance is 1,000 pF for all coils. The old coils are on 80 and 20 meters. The old coil data are:

L1: Primary, 25 turns #30 Formvar on 3/8" form with slug. Cover with a layer of tape and wind center-tapped secondary of 20 turns #30 over the primary. Coil form is



■ FIGURE 6

Cambridge Thermionic type LS-3.

L2: 45 turns #30 wire on 3/8" form with slug (Cambridge Thermionic type LS-3); 100 pF in parallel.

L3: 36 inches of #30 wire tapped 12 inches from crystal end, wound on 3/8" form with slug (Cambridge Thermionic type LS-3).

A The Cambridge Thermionic coil forms are obsolete and I could not find data, but I suspect that the number of turns would be more than will fit on the form. I found CWS Bytemark, a company that supplies magnetic components to the amateur and experimenter market (www.bytemark.com). Their minimum order is \$25 but that is better than the \$100 minimum order of most suppliers. Bytemark has a ferrite pot core that is good in this frequency range but it is not tunable. I think the L-57 shielded coil form with tuning slug is better suited and it has a bobbin that will make winding easier. The coil form has six terminals to allow a center-tapped primary and secondary. The L57-3 is rated for 10 kHz to 500 kHz and will produce 204 microhenries (μH) with 100 turns.

With a tuning capacitance of 1,000 pF, the required inductance is 633 microhenries (0.633 mH). Using the relation: Turns = $\sqrt{((\text{desired } L)/(90\% \cdot \mu H/100T))}$, I come up with the number of turns = 167. The 90% factor is just to provide the tuning range. The slug will tune the coil 2:1 so there should be no problem

reaching 200 kHz.

For the coil L1, you will want a secondary of $20 \cdot 167/25 = 134$ turns center-tapped. That is 301 turns total; let us see if #30 wire will fit: I calculate the winding area of the bobbin to be 0.03 sq in and from tables find that #30 wire uses 7,000 turns per sq in; $0.03 \cdot 7000 = 210$ turns max, so it won't fit. Try #34 wire which is 16,000 turns/sq in * $0.03 = 480$ turns max. That will fit. Keep in mind that the tables are for machine wound coils so hand-winding will result in less turns fitting in the max dimension. Coil L2 has no secondary so 167 turns #30 will fit okay or you can use 167 turns #34 wire. Coil L3 wants a tap 1/3 up the winding so it will be 167 turns with a tap at 56 turns.

For 175 kHz, you could increase the capacitance to 1,304 pF and use the same coils or increase the inductance to 827 μH to use 1,000 pF. There should be enough range in the slug tuning to reach both frequencies with the same coil, but I don't know that 167 turns will do it. The number of turns for 827 μH (reduced 10% for tuning) is 212 turns. L1 will have a secondary of 170 turns center-tapped; that will be tight using #34 wire but could fit. Coil L2 has 212 turns; not a problem, and L3 wants a tap at 71 turns.

You may be interested in my setup for winding coils. I am using a portable drill that had a dead battery so I drive it with a power supply (it needs to supply at least one amp). A dowel taped to the chuck operates a

microswitch and a three digit counter.

Figure 5 is a photo and **Figure 6** is the schematic of the counter.

SOFT START AC CIRCUITS

Q I would like to build a soft start circuit for a standard household incandescent light bulb (100W).

What circuit options do I have?

— Dean Larsen

A Incandescent light bulbs are passé; I would rather answer a question about fluorescent or LED lights!

However, a soft start will extend the life of a light bulb as will lower voltage. I don't recommend a PWM solution because that will waste 20 or 25 watts and the light bulb is already wasting 99.9 watts. A thermistor in series with the light bulb will give a soft start and also reduce the voltage slightly, and extend the life tremendously. The 100 watt bulb is about 10 ohms at room temperature, so the inrush current is 12 amps peak with no thermistor. Mouser part number 871-B57153S330M is 33 ohms at room temperature and about one ohm with one amp of current flowing through it. The inrush current is reduced to $120/43 = 2.8$ amps peak and the operating voltage is reduced about one volt. That is not enough that you will notice a difference in the light output but the life will be extended. **NV**

MAILBAG

Dear Russell,

Re: 60 volt, 13 amp supply, December 2008, page 24. I absolutely love your response on this switching supply. You made it so simple that I could understand nearly all of it and I looked up the rest! I would like you to be more specific about the Magnetics, Inc., manual for ferrite cores. I've been cruising around their website and I'm not sure which one to download ... or is it something I have to purchase?

— Chuck Larson

Response: Go to this site:

www.mag-inc.com/ferrites/fc601.asp and choose either the uncut or sectioned versions. There is no cost.

Dear Russell,

Re: Blinking Lamp Schematic, December 2008, page 26. Hi – I am almost a complete novice. I enjoy reading your magazine and trying to follow along. I was reading the "Blinking Lamp schematic" discussion and have a follow-up question. The schematic shows C1 in parallel with R1 and R2. Is that correct? Shouldn't C1 be in series

with R1 and R2? And shouldn't C1 be connected to ground?

— Russ Hintze

Response: My connection of C1 is a little bit unorthodox but the +12 volt supply is virtual ground, so it works the same as if C1 were grounded. However, noise on the power supply will cause timing problems, so this only works if the power supply is clean.

Dear Russell,

Re: How to Measure Impedance, December 2008, page 25. I believe



Bob J., in the Dec. 2008 issue is looking for a simpler solution to the question, "How to Measure Impedance." This is how it was done in the olden days: Wire a 25 ohm pot in series with Zx (the unknown speaker). Connect one AC voltmeter across the pot and one AC voltmeter across Zx. Connect an audio generator tuned to 400 Hz across both R and Zx. Adjust the pot for equal meter readings. Remove the pot from the circuit. The DC resistance of the pot is the impedance of the speaker. Great column. Tnx WA8IAA

— Tom Rees

Response: Thanks for the feedback, Tom.

Dear Russell,

Re: FM Shutdown Problem, January 2009, page 28. I have no personal experience with FM translator equipment, but given that the Federal Communications Commission (FCC) issued a set of rules for translators in June 1991 (see www.fcc.gov/mb/audio/translator.html) which include the requirement that translator stations stop transmitting if the signal from the primary station is lost, it would seem that any type-accepted commercial translator equipment manufactured since then would already have an automatic mute or squelch function built in which will mute the transmitted audio and cut off the translator carrier after a short

period of continuous primary signal loss. This may have an adjustable threshold and if it is set improperly, the translator will (illegally) transmit noise upon loss of the primary signal. It should not be necessary for a translator user to add this function. By the way, it's fairly common for FM receivers to employ AGC to control their front-end gain in order to minimize intermodulation distortion; some even have two AGC loops to accommodate a wide range of signal strengths with the second loop acting on the intermediate frequency stages. The receiver in the Tepco J340 translator is one such unit. (www.rapidnet.com/~tepcos/j340.htm). I enjoy the Q&A column and get many good ideas from it.

— Keith Kunde, K8KK

Response: Thanks for the feedback, Keith. It appears that what Bob Ziller needed was a manual for his translator.

Dear Russell,

Re: Stable Constant Current, January 2009, page 27. I really enjoy your column every month. Since I am presently working with a current source for a project, they are front and center in my mind. I couldn't help but notice a small oversight in your method, having built a "low ohmmeter" in the past. If the reader is going to use this circuit for a piece of manual test equipment, I believe there could be a significant, unpredictable drift in current upon initial application.

Even with the two compensation diodes glued to the transistor, the V_{be} will move faster than the diode's drops, until thermal equilibrium.

One possible solution would be to put a >10A Schottky diode across the output. This would allow for the unit to run at rated output continuously and reach a stable temperature and current.

A second possible solution which would have an essentially flat tempco, is to use a TL431 adjustable reference, a .25 ohm >25W current sense resistor, and an NPN pass transistor with a gain > 100 at 10A. Check out the TL431 datasheet for the application note. A 2N6284 and a couple of 0.5 ohm 20W thick film mountable resistors should work.

Years ago, I built a low ohm meter to check the resistance of the field winding for a military alternator. The windings had to be between 1.8 and 2 ohms. Production was having fits trying to use our calibrated Fluke DMM, as you can imagine. I built a low ohm converter box that contained an LM317 adjustable regulator configured as a 100 milliamp current source. Two Kelvin probes were constructed by gluing and heat shrinking two straight test probes together, side by side. These parallel prongs would sit nicely on the two round slip rings of the rotor. One side of each Kelvin probe went to the current source, and the other side terminated at front panel banana jacks for connection to the DMM. A 4.7 volt Zener was put across the output of the current source to keep it loaded (and not over-drive the meter) and the DMM was locked in the four volt range. The government inspector signed off on this homemade solution because we could prove the output current and resultant voltage with a calibrated meter; plus, Ohm's Law is a known formula.

Fortunately, this was not the same inspector that made us buy a calibrated metal ruler to measure the size of a cardboard shipping box! A Stanley tape measure was not good enough. I kid you not.

— Tim Young

Response: Thanks for the feedback, Tim. You are correct about the thermal equilibrium, it sometimes takes a long time. The diode is a good idea but it should be switched to take it out of the circuit while measuring. Your idea of using a TL431 is a good one; check out my improved circuit in the March issue.

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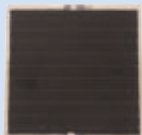


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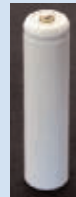


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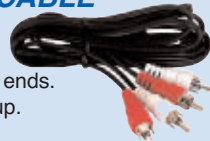


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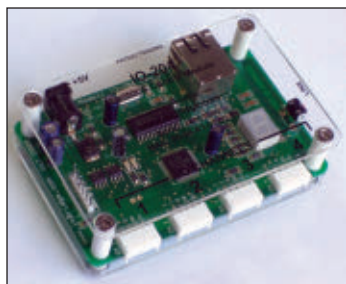
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WEB-BASED, REMOTE CONTROL, AND MONITORING PLATFORM

After completion of world-wide beta testing, ioBridge Corporation announces the release of the IO-204 Monitor and Control Module and its integrated web service. Along with a set of online tools, the



module allows for easy creation of interactive web-based projects. ioBridge solves the hardware and software problems associated with getting projects online including network configuration, web programming, mass deployment, and security.

"Judging by the creativity and popularity of our customer's projects, I believe we have incredible potential," said Jason Winters, President of ioBridge. "People are making household power monitors that chart real-time usage on blogs. The ioBridge platform is being used to make interactive aquariums, Twittering kitchen appliances, and iPhone-controlled garage doors and locks. Ease of use was one of our main design goals. Nothing demonstrates that better than discovering an Internet operated dog food dispenser created by a middle school student."

The IO-204 Monitor and Control Module eliminates the need to run a local web server, track dynamic IP addresses, or even open firewall ports. Once the IO-204 is networked using Ethernet, the module operates over an encrypted connection with ioBridge web services. This connection establishes a gateway to handle monitoring and remote control with devices connected to the IO-204.

By itself, the IO-204 Monitor and Control Module can control digital outputs and monitor both digital and analog inputs. However, more advanced functions are capable

through a suite of interface boards that allow for instant project integration. Interface boards are available for relay control, temperature measurement, servo control, X10 home automation, and

serial communication.

ioBridge modules tie into integrated web services hosted by **ioBridge.com** allowing for web-based configuration, control, and real-time monitoring. Access to the module is compatible with web browsers and mobile devices such as the BlackBerry and iPhone. ioBridge acts as a hub for module-to-module connections, allowing for interconnected projects spanning the globe. Supported web services include event-based text and email messaging alerts, Twitter and UberNote integration, and data reporting with Google Charts.

Web widgets — used for monitoring inputs or controlling outputs — are created using step-by-step wizards to eliminate complex microcontroller and web programming. ioBridge offers a secure dashboard to access widgets and copy-and-paste embed codes to drop widgets into existing web pages. Users have the ability to extend the system using an open API for desktop and web application integration.

ioBridge is supported by an active community of developers and users. Collectively, they have created projects featured in *Popular Science*, *Digg*, *Wired*, *Instructables*, *Hack-a-Day*, and *Make*.

For more information, contact:
ioBridge Corporation
Web: www.iobridge.com

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continued on page 91

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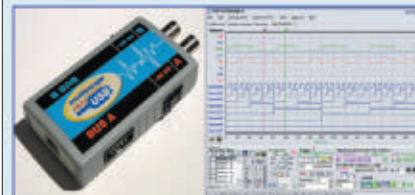


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BUILD THE rCube TALKING VOICE MEMO ALARM CLOCK

By Dave Decker

In this project, we're going to introduce you to a unique talking voice memo alarm clock/MP3 speaker with customizable alarm music. The device can capture a tune from your PC or MP3 player and store it in internal, non-volatile Flash memory for use as the alarm. In addition, we've also compiled an online library of royalty-free music clips and sound effects, and created a unique way of downloading them directly to the clock. Either way, music is retained indefinitely, even without power.

A very unique feature of our clock is the capability of recording voice memos using a built-in microphone. This feature makes it easy to leave yourself a wakeup reminder, since recorded voice memos can also serve as the alarm. A 10 minute snooze timer, progressive alarm volume (the alarm gradually gets louder), and a daily alarm are included.

The 4 1/2" cube-shaped, injection-molded case includes a translucent acrylic shade illuminated from within by 16 high brightness LEDs. The LEDs allow the clock to double as a nightlight and they create entertaining synchronized lightshows when the MP3 speaker feature is used. A four-digit auto-dimming LED display shows the current time, indoor temperature, scrolling text, and animations while in MP3 mode.

There's a good selection of built-in nightlight programs to choose from including solid, fading, and random color patterns. Some of the nightlight programs are designed to react to their surroundings. For example, the "clap" nightlight turns the light on and off in response to hand claps. There's an on-at-dusk simulated candle flame nightlight, a "babysitter" nightlight that plays/fades out a lullaby when it hears a baby crying, and even a sound soother nightlight to help you fall asleep.



This unique talking clock and MP3 speaker can record voice memos or your favorite music for the alarm, and it doubles as a smart interactive nightlight, too. But wait, there's more!

Press the large backlit button and the talking clock announces the current time in a natural-sounding male voice. There's a recessed pocket in the front face of the button designed for a standard 1 3/4" x 1/2" return address label. Using an inkjet or laser printer and labels (we recommend the white polyester type), it's easy to create artwork featuring any university or team logo, a child's name, or any other design to further personalize the clock. The button and label are backlit by a pair of white LEDs, making them glow softly.

On the back of the device, there's a smaller "mode" button and a 3.5 mm audio input for your iPod/MP3 player recessed into the base. The mode button is used to select the current nightlight program and to activate the voice-prompted settings menu. The talking menu makes it easy to set the time, the alarm, and other features.

If you prefer, the clock can be set up and managed entirely using your web browser. It listens for sounds generated by a special webpage and responds by setting the time, configuring the alarm, selecting your favorite nightlight, and even calibrating the temperature sensor. It's as easy as clicking your mouse, and it's a lot of fun, too!

The clock can use either the AC adapter or a standard 9V battery for power, so it's easy to take it anywhere. The battery also serves as a backup for the clock in case of power failure. There's even an integrated smart battery charger that maintains your (optional rechargeable) battery in peak condition.

Theory of Operation

We'll present the circuitry in two parts: a "core"

portion (shown in blue) which includes the power supplies, charger, light sensor, beat detector, LED drivers, main processor, and audio subsystem; and a “display” portion (shown in green) containing the LED display, secondary processor, and temperature sensing circuitry. Although we show building the core and the display portions on different PCBs, there’s no reason you couldn’t build the entire design on a single board if you wanted.

The core board is designed around two important components: a Microchip PIC16F73 (U1) and a Nuvoton ISD17120 record/playback IC (U2). The PIC16F73 includes 4K words (7 kB) Flash memory, 192 bytes RAM, and an eight-bit A/D converter. The PIC also contains software written in Assembly language, which controls virtually every aspect of the clock’s behavior.

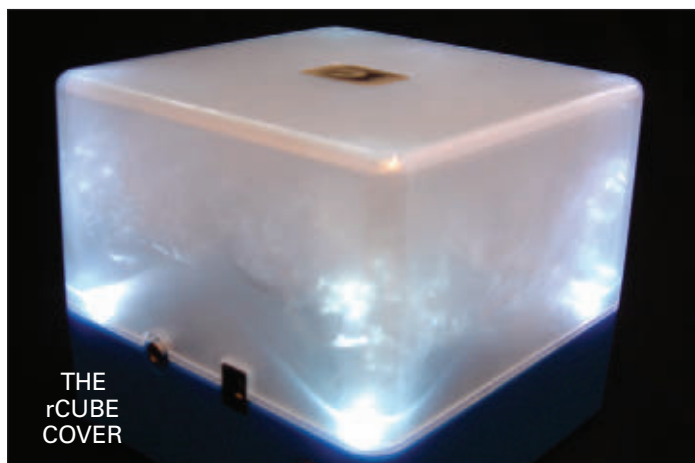
Audio Record/Playback with the ISD17120

The ISD17120 integrates most of the audio related hardware, including audio recording and playback subsystems, a large internal Flash memory, a microphone preamp with automatic gain control (AGC), a programmable audio mixer, and a class D audio amplifier.

The PIC and ISD communicate using a serial interface (SPI). The PIC is the master and sends commands to the ISD using the MOSI data line (master-out-slave-in). The ISD sends data on the MISO data line (master-in-slave-out). The /SS control line (slave select) is used to get the ISD’s attention. The SCLK line (serial clock) provides a clock to coordinate data transfer on the MISO and MOSI lines.

Some ISD commands take a long time (milliseconds) to execute, such as when the PIC asks the ISD to erase a portion of Flash memory. Because the PIC has a lot to do, we didn’t want to force it to wait around repeatedly asking the ISD whether it is finished (this is called polling and the ISD supports it though we don’t use it here). For efficiency, we chose to configure the ISD to drive the /INT line low whenever it completes any operation, thereby causing an interrupt on the PIC.

The ISD’s audio amp connects directly to the speaker. Class D amps are a modern type of digital switching amplifier used in many portable devices such as mobile phones and MP3 players. They run cooler and use less power than classical amplifiers because their output transistors are always either fully on or fully off. The output transistors in conventional amps are always part way on, even when there is no signal present. This wastes power and creates heat — two things we’d like to avoid here in order to make the most of our battery. The ISD also supports a dynamic microphone input. The integrated microphone preamp with automatic gain control (AGC) adjusts to the level of your voice automatically. There’s also an analog input (pin 9) which we’ll use for our external MP3 audio input. C9/C10 and R6/R7 work as high-pass filters and they also mix the stereo channels together into a mono signal for the ISD.

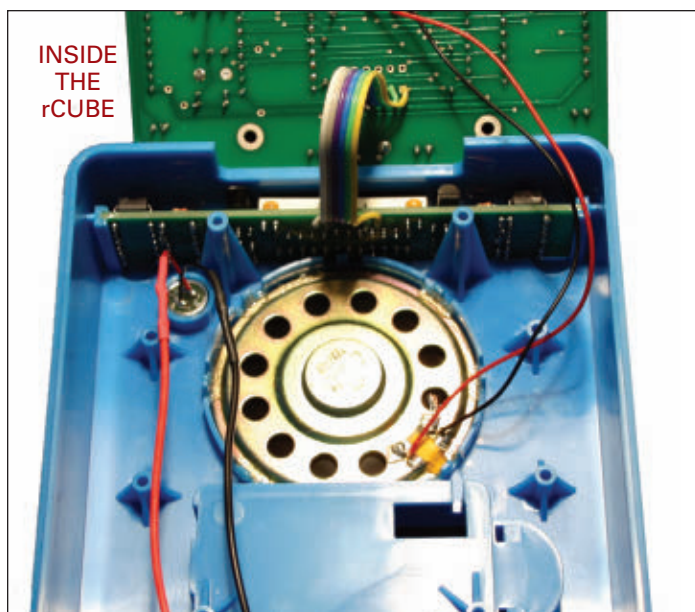


Audio Beat Detector

The pair of op-amps on the far right of the schematic forms an “audio beat detector.” When a beat is detected, the output of the second op-amp (U3 pin 7) goes low briefly, causing an interrupt on the PIC.

The beat detector contains three functional blocks. The first block— formed by 1/4 of U3 and C20/R17 — is a differentiator. The purpose of the differentiator is to produce an output voltage proportional to the rate at which the audio input voltage is changing. When the input is constant, the output is close to 0V. When the input changes very quickly (as it tends to do when there is a beat), the output reaches nearly 5V.

The second block is a “peak-hold” circuit formed by D4/C19/R16. The purpose of this circuit is to detect only the peaks in the audio signal, and to discard duplicate beats that occur within a short time period (about 22 ms with the component values shown). The last block works as a voltage comparator. R14/R15 produce a reference of approximately 2.5 volts at U3 pin 5. When the voltage on



C19 is greater than the reference threshold, U3 pin 7 goes low. This converts the fluctuating voltage on C19 into a clean digital signal for the PIC.

Power Supplies

There are two 5V regulated DC power supplies based on different topologies: one linear supply and one switching supply. Both are powered by the unregulated AC adapter or the 9V backup battery through the diode OR circuit formed by D1/D2. The higher voltage “wins” and supplies current to both regulated supplies. You might ask, “Why include two power supplies in the design?” The switching supply can be shut down when the clock is sleeping, conserving battery power. The linear supply (marked +5R1) is built around the LP2950 linear regulator (U4), which can supply up to 100 mA. The LP2950 was selected due to its low quiescent current (75 μ A). Quiescent current is the penalty for maintaining regulator operation when nearly zero current is required, as during sleep. Notice the linear supply is only connected to components that require power when the clock is sleeping (+5R1). Everything else runs off of the second supply.

The switching 5V supply (marked +5R2) is a step-down or “buck” type converter built around the LM2574 (U7) and rated to supply up to 500 mA. Switching supplies are usually more complex than linear supplies, but they’re also much more efficient. U7 operates at a fixed frequency of 52 kHz, constantly transferring very small packets of charge from the battery into L1/C2. A 1N5819 “fast” Schottky catch diode provides a current return path as the magnetic field in L1 collapses during each cycle. U7 only transfers as much charge as required to maintain 5V across C2, and because this switching supply is highly efficient, U7 doesn’t get hot. When the PIC drives U7 pin 3 high, the switching supply shuts down, conserving battery power.

LED Drivers

A pair of eight-bit serial-in parallel-out shift registers (U5/U6) are used as LED drivers. This approach avoids the need to use large numbers of I/O pins to drive the LEDs. We could have chosen to drive the 16 LEDs in a 4x4 array, but the PIC would have spent a lot of time constantly multiplexing rows and columns, and there are other things we wanted it to do instead. To light a particular pattern of LEDs, the PIC simply sends eight bits of data to each shift register. Since the clock lines of U5 and U6 are tied together, the PIC writes out two bits at a time (one to each chip), speeding the process. The remaining two white LEDs forming the button backlight

are driven directly by the PIC.

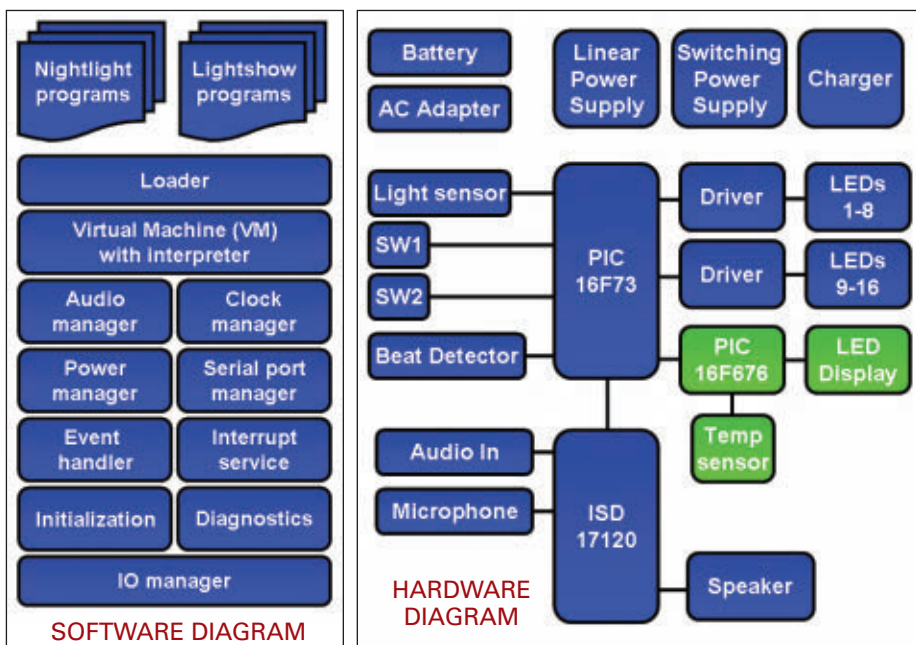
Everything Else

R19/R20 and 1/4 of quad op-amp U3 are used to measure the battery voltage, which appears as an analog voltage at U1 pin 2. The op-amp is configured as a voltage follower, allowing U1’s A/D converter to quickly sample the voltage level even though only a very small current is available through R19/R20. If the op-amp were not used, it would take considerably longer to charge up the sample “holding” capacitor (inside the PIC’s A/D converter circuitry), thus significantly lengthening the overall A/D conversion time. D3/R11/R13/R18/Q3/D5 and 1/4 of U3 are used to measure the ambient light level. Q3 is a photo-transistor which reacts to visible light. Before measuring the light level, the PIC turns off all the LEDs very briefly so that their light output doesn’t interfere with the ambient light measurement. It waits a few hundred microseconds for Q3 to settle and then samples the voltage at U1 pin 3.

R2/Q2/R1/R4/Q1/R3/D7 form the battery charger. When U1 pin 7 is driven high, transistors Q2 and Q1 switch on, allowing a charging current to flow through Q1, R3, and D7, and into battery B1. R3 limits the charging current to a safe level. The software manages the charger, turning it on and off as required. A pulse width modulated (PWM) charging algorithm is used, which continuously alternates between charging the battery and allowing it to rest every few seconds. As the battery gains more charge, the algorithm gradually reduces the duration of the charging pulses accordingly.

The Display

The clock display board features a PIC16F676 microcontroller with 1K words (1.7 kB) Flash, 64 bytes



RAM, 128 bytes EEPROM, and a 10-bit A/D converter. This PIC contains an internal 4 MHz clock. The display board is powered through SP1, which also carries the inbound (SP1DATAOUT) and outbound (SP1DATAIN) serial port data lines used for communication. U2 holds one row for display on DISP1, a four-digit seven-segment common-anode LED display. The CLK and B lines are used to shift

data into U2 one bit at a time. The PIC places a data bit on B, then pulses CLK low to shift the bit into the shift register. The software includes a multiplexing algorithm for managing DISP1 by repeatedly shifting a row into U2, and switching on the next column transistor Q1-Q5. The software also manages displaying animated patterns (stored in EEPROM) and scrolling the nightlight/lightshow names across the display.

U3 is an LM350Z precision temperature sensor, and its output is connected to U1 pin 10. To determine the current temperature, U1 uses its 10-bit A/D converter to measure the voltage across U3, then scales and converts the reading to degrees Fahrenheit.

Software

The software diagram shows some of the main software components for the core PIC. Perhaps the most interesting feature of the core software is that it includes a virtual machine (VM). The VM provides an interpreter (think Basic or Java, but simpler) and a protected environment in which nightlight and lightshow programs run. When a nightlight or lightshow program is selected, a loader initializes the VM's execution environment, points the interpreter to the selected program in memory, and starts the interpreter.

The lightshow and nightlight programs are written in a proprietary high-level language used exclusively by the VM. These programs are not written in PIC machine code and they do not run on the PIC directly. This approach ensures that a night-light program can't crash the clock due to some bug — like getting into an infinite loop or trying to jump to an invalid memory location. Also, the VM grants the program only limited time and resources to run, so the core software can perform other activities in the background (like maintaining the clock, monitoring the battery charging cycle, or counting beats in your music).

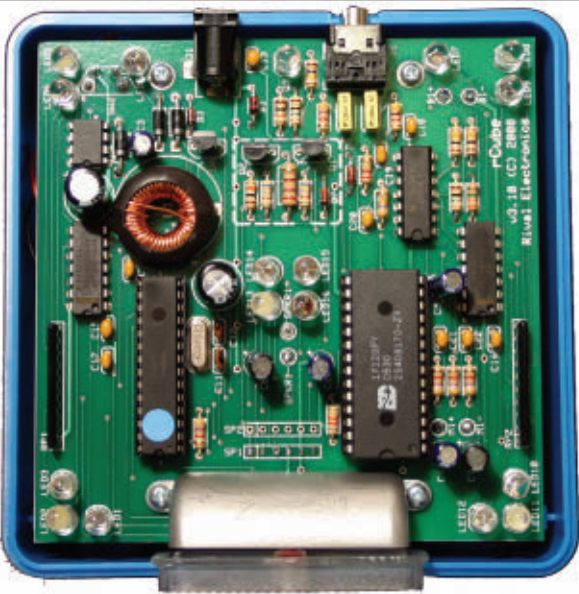
Whenever there is something pressing to do, the VM temporarily suspends the interpreter (and thus pauses the nightlight or lightshow program's execution) and allows the

PARTS LIST

ITEM	QTY	DESCRIPTION	SUPPLIER	PART#
□ R1	1	1K resistor, 1/4W (brown, black, red)	Jameco	690865
□ R2, R4	2	6.8K resistor, 1/4W (blue, gray, red)	Jameco	691067
□ R3	1	270 ohm resistor, 1/2W (red, violet, brown)	Jameco	661360
□ R5-R10	6	4.7K resistor, 1/4W (yellow, violet, red)	Jameco	691024
□ R11	1	10K resistor, 1/4W (brown, black, orange)	Jameco	691104
□ R12	1	82K resistor, 1/4W (gray, red, orange)	Jameco	691323
□ R13- R15	3	100K resistor, 1/4W (brown, black, yellow)	Jameco	691340
□ R16	1	220K resistor, 1/4W (red, red, yellow)	Jameco	691420
□ R17	1	470K resistor, 1/4W (yellow, violet, yellow)	Jameco	691500
□ R18, R19	2	1M resistor, 1/4W (brown, black, green)	Jameco	691585
□ R20	1	3.3M resistor, 1/4W (orange, orange, green)	Jameco	691690
□ RP1, RP2	2	220 ohm resistor pack (10-pin SIP)	Mouser	266-180
□ C1, C2	2	220 µF electrolytic capacitor (16V or greater)	Mouser	140-XRL35V220-RC
□ C3	1	22 µF electrolytic capacitor (16V or greater)	Digi-Key	P5162-ND
□ C4-C6	3	10 µF electrolytic capacitor (16V or greater)	Digi-Key	P5161-ND
□ C7, C8	2	4.7 µF electrolytic capacitor (16V or greater)	Digi-Key	493-1056-ND
□ C9, C10	2	0.1 µF polyester capacitor	Mouser	581-BQ014D0124J
□ C11, C12	2	15 µF disc capacitor	Jameco	332208
□ C13-C22	10	0.1 µF bypass capacitor (any type is okay)	AllElectronics	M-104
□ L1	1	330 µH toroidal inductor	Jameco	371670
□ D1, D2	2	1N4001 diode	Mouser	821-1N4001
□ D3, D4, D7	3	1N914 diode	Mouser	78-1N914
□ D5	1	1N5231 zener diode (5.1V)	Mouser	512-1N5231B
□ D6	1	1N5819 Schottky diode	Jameco	177965PS
□ Q1	1	2N3906 PNP transistor	Mouser	512-2N3906TA
□ Q2	1	2N3904 NPN transistor	Jameco	38359
□ Q3	1	NPN phototransistor	Jameco	373000
□ X1	1	4.000 MHz crystal	Mouser	815-ABL-4B2
□ SW1	1	SPST pushbutton switch (short actuator)	Mouser	612-TL1105R-250
□ SW2	1	SPST pushbutton switch (long actuator)	Jameco	202956
□ J1	1	2.5 mm DC power jack	All Electronics	DCJ-6
□ J2	1	3.5 mm audio jack	All Electronics	MJW-11
□ LED1				
-LED18	18	High brightness LEDs (four blue, seven white, two red, two green, one yellow, one orange, one purple)	Rival Electronics	B501, B502
□ U1	1	Microchip PIC16F73 (programmed)	Rival Electronics	B212
□ U2	1	ISD17120 Sound record/playback IC	Digikay	ISD17120PY-ND
□ U3	1	LM224N quad op-amp	Jameco	212118
□ U4	1	P2950 5V linear voltage regulator	Jameco	266757CB
□ U5, U6	2	74HC164N serial-in, parallel-out shift register	Mouser	511-M74HC164
□ U7	1	LM2574 switching regulator	Jameco	156566
□ SPKR1	1	Speaker, 2.25" diameter, 8 ohm	Mouser	254-PS610
□ M1	1	Dynamic microphone element	All Electronics	MIC-74
□ BC1	1	9V battery clip	Jameco	109154PS
□ AC1	1	9 VDC unregulated AC adapter, 300 mA, 2.5 mm	All Electronics	DCTX-934

PARTS LIST (DISPLAY)

ITEM	QTY	DESCRIPTION	SUPPLIER	PART#
□ R1-R5, R13, R14	7	3.3K resistor, 1/8W (orange, orange, red)	Mouser	299-3.3K-RC
□ R6-R12	7	220 ohm resistor, 1/8W (blue, gray, red)	Mouser	299-220/AP-RC
□ C1, C2	2	0.1 µF bypass capacitor (any type is okay)	All Electronics	RM-104
□ Q1-Q5	5	2N3906 PNP transistor	Mouser	512-2N3906TA
□ U1	1	Microchip PIC16F676 (programmed)	Rival Electronics	B213
□ U2	1	74HC164N serial-in, parallel-out shift register	Mouser	511-M74HC164
□ U3	1	LM335Z precision temperature sensor	Mouser	511-LM335Z
□ DISP1	1	4-character, seven-segment LED display	Rival Electronics	B509



core software to run for a little while (about 750 μ s in the worst case, but typically much less). Since the background activities are designed to be very efficient, the interpreter is quickly given control again and execution resumes with no perceptible delay. Even with all the clock's background activities taking place, the interpreter can read, decode, and execute several thousand instructions per second so there is no visible delay to the human eye. The nightlight and lightshow programs have features typical of high-level languages such as comments, control structures, subroutines, and conditional expressions. A lightshow program to light up LED1 when the beat count in your music is ≤ 120 BPM and light up LED 2 when its > 120 BPM would look like this:

```
Repeat | Forever ; do this forever
  When | BPM | LE | BPM120 ; true if BPM  $\leq 120$ 
    Enable | LED1, 100 ; enable LED1 (for 1 sec)
  Otherwise
    Enable | LED2, 100 ; enable LED2 (for 1 sec)
  EndWhen
EndRepeat
```

The programs are stored in tokenized form, so this example program occupies only nine (14-bit) words in Flash memory. The interpreter/VM would run this program continuously until something more important happened (like it was time for the alarm to go off, or someone pressed a key to select a different nightlight).

Other major software components include an initialization module used to set up the hardware during boot, a diagnostics module, a central event handler, an interrupt service routine, a serial port manager to send/receive data on SP1, an audio manager to control interactions with the ISD chip, a clock module to maintain the real-time clock and alarm functions, a power manager to handle sleep/wake, an LED manager, a battery charging module

including the (PWM) charging algorithm, a speech manager to sequence the playback of complex multi-word phrases, and an online setup module to decode and execute commands from the website. There are a few other modules used to control voice memo recording/playback, capture audio clips, a timer module to manage a pool of eight software timers, and a few other miscellaneous utilities. To explore the complex software in more depth, you can see the detailed technical manuals included in the kit or download it from the *Nuts & Volts* website at www.nutsvolts.com) or our website at www.rivalonline.com/downloads.

Building the Clock

You can use the custom plastic injection-molded case and PCBs, but there's nothing to prevent you from building this project on your own perfboard or using a different case. When designing your own PCBs, there are a few layout precautions that should be observed. First, the switching power supply has the potential to generate considerable noise, so the wiring around U7/L1 should be kept short. The audio and microphone inputs are especially prone to picking up noise, so keep other wiring (especially the switching power supply components) away from these inputs. The physical layout of the LEDs isn't critical, though we think that grouping them in the corners and center of the PCB makes for a pleasing display.

The main PCB is assembled first, starting with resistors R1-R20. We're going to work our way up in terms of height of the components to make the soldering a bit easier, so the shortest components get installed first. Insert each resistor in the appropriate location on the board, then flip the board over and solder in place. You may want to tack just one side of the component first, then check to see if it is sitting fully flat against the board before finishing the other leg. Insert/solder diodes D1-D7 next, paying particular attention to their orientation. The banded cathode end of each diode should be toward the left side, as marked on the board. Also, check carefully as D6 looks similar to D1/D2 and D5 looks similar to D3/D4/D7.

Continue by installing the non-polarized capacitors C9-C22 and the resistor packs RP1, RP2. The resistor packs have a faint white dot on one end which needs to be oriented toward the left end of the PCB. Next, install X1, Q1, Q2, Q3, U4, and L1. Note that Q1, Q2, and U4 look similar and they must be installed in the correct direction. Install SW1 (the short actuator), J1, and J2 paying particular attention that these components fit fully flat and square against the PCB. This is important to ensure a good mechanical alignment with the case.

Next, install the 18 LEDs. Note that they must be installed in the correct orientation in order to work. Normally, the flat side of each LED points toward the top of the PCB, however, we have identified a few manufacturers which break this convention. If one or more of the LED color groups included in a kit is marked as "reversed," you

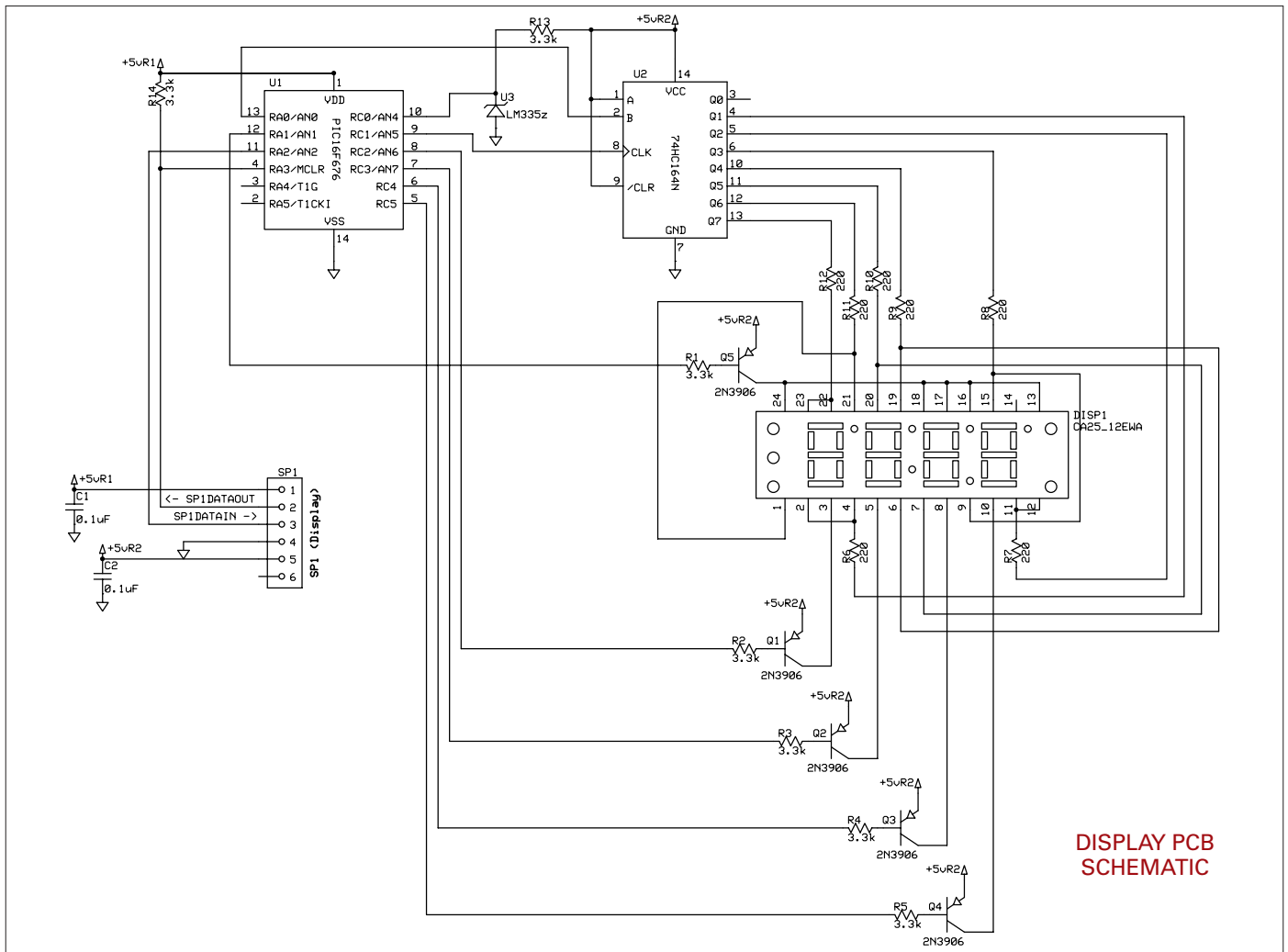
should install the LEDs in that particular color group with the flat side toward the bottom instead of toward the top of the PCB. Working with one color at a time, install the 18 LEDs as follows: seven white LEDs (LED2, LED5, LED8, LED11, LED13, LED17, LED18); four blue (LED1, LED4, LED7, LED10); two green (LED3, LED12); two red (LED6, LED9); one orange (LED14); one violet (LED15); and one yellow (LED16). Next, install the ICs and sockets. Note that all ICs are inserted with the notch/dot toward the left end of the PCB. Install sockets for U1 and U2, then install U3, U5, U6, and U7 (no sockets required). Install the electrolytic capacitors C1-C8, making sure to orient them with the correct polarity as marked on the PCB.

Flip the board over and install SW2, the battery clip BC1, the microphone M1 (note polarity: red = +; black = -), and the speaker SPRK1 using the speaker wires provided. Make sure SW2 is installed fully flat against the PCB and square for good alignment with the case. Do not shorten the wires for M1, BC1, or SPRK1 as they must be long enough to allow these components to fit properly into the enclosure. Finally, flip the board back over and press U1 and U2 firmly into their sockets. This completes the assembly of the core board.

Working now with the display board, install R1-R14 (these 1/8 W resistors are quite small and delicate, so handle/solder carefully). Install C1 and C2 next, then U1, U2. The notches on U1 and U2 go toward the top of the PCB. Clearance with the case is tight, so Q1-Q5 and U3 should be installed as close to the PCB as possible. You'll want to test-fit the display PCB into the vertical slots in the plastic base to see how much room is available before soldering Q1-Q5 and U3 in place — they need to be quite close to the PCB to fit properly. U3 looks a lot like Q1-Q5, so please check carefully. All these components should be installed with the flat side toward the top of the PCB. Install DISP1 next, paying particular attention to its orientation. This part has quite a few pins, so make sure that you don't solder it in backwards! The printed part identification lettering on DISP1 should be on the bottom edge. Complete the display board by flipping it over and soldering one end of the six-conductor ribbon cable to the underside of the board at SP1. The display board is now complete.

Inspecting Your Work

Double-check that all ICs on both boards are inserted



troubleshooting guide or check our online user forum for assistance. Disconnect power, then turn the core PCB and display PCB upside down with the core PCB on the left and the display PCB on the right. SW2 should be on the upper left and the ribbon cable should be coming off the left edge of the display board and going toward the core board on the left. Connect the six-conductor ribbon cable to the underside of the core PCB so there is no twist in the cable.

Pin1 (the square pad) on both boards should be connected together. Power the boards up again for a final test while holding down SW2, making sure the mic, speaker, and battery clip don't touch the PCBs. You should see "88:88" displayed on DISP1. Release SW2 and the clock should reboot. It should briefly show "Hi" on the display, scroll the current nightlight name a few times ("Solid_1"), then show the indoor temperature (probably "72F" or similar). Finally, the display should flash "12:01" (since the time hasn't been set).

Mechanical Assembly

Once everything checks out, attach the self-adhesive bumpers into the recessed feet on the bottom of the plastic base, carefully slide the display PCB into the vertical slots in the base, and set the speaker and mic into the cups provided. Secure the speaker and mic with a couple small dabs of adhesive and allow it to dry. Set the core PCB inside the base on the four plastic bosses. Install the button, the backlight shroud, and use the four screws provided to secure the PCB to the base (the longer screws go in the front). Rest the acrylic shade on the base and temporarily secure it with some transparent tape. Apply all the labels. Test your kit thoroughly, making sure all the features work correctly as described in the user manual.

Wrap Up

There's a lot of interesting technology in this project and many of you will want to learn more. We've created several technical documents describing the hardware and software in greater detail which are included with each kit and may also be downloaded from our website www.rivalonline.com/phpBBRival/index.php.

We hope you have as much fun building and using this clock as we had

creating it. You'll enjoy showing off your work and learn a lot in the process, too! **NV**

A complete kit or an assembled rCube for this project can be purchased from the *Nuts & Volts* Webstore @ www.nutsvolts.com or call our order desk, 800 783-4624.

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HOW TO PARALLEL POWER SUPPLIES FOR HIGHER OUTPUT

BY FERNANDO GARCIA

This project started in a roundabout way. I had been interested in assembling a Class D amplifier for quite some time, but had not found the time or motivation to do it. When my subwoofer amp died and I found it too expensive to repair, I was motivated to finally delve into Class D. Searching the Internet, I found some pretty good and reasonably priced kits, which I promptly bought.

By now, you may be wondering why this article is not named a Class D amp project instead. The reason is that all amplifiers require a good power supply. Class D amps in particular require a tightly regulated supply for two reasons. The first is to maximize power output; it must get as close to the amp's maximum voltage rating without exceeding it and thus destroying it. The second is that these amps operate with very low feedback which makes them quite susceptible to powerline ripple (otherwise known as hum) — not a good thing on a sub amp.

Again searching the Internet, I found many opinions on suitable power supplies, but they all agreed with my original findings: a tightly regulated supply is a must. Some people advocated the use of a linear regulator, but I felt that its low efficiency would negate the Class D's major strength: its high efficiency. Thus, I decided to use a switchmode regulator. *NOTE: If you feel daunted by the complexities of a switchmode supply, you may try the simpler approach discussed in the **sidebar**, which employs common adjustable three-terminal regulators.*

So, what controller type should I use? I decided on National Semiconductor's line of Simple Switchers as they are relatively simple to design, reliable, and widely available. Next question: what type of switchmode topology? At first, I thought about using a buck regulator. However, simulating the circuit with National's software, it became readily apparent that a buck regulator simply was not a feasible option. The output voltage level the project required (32 VDC) — with enough margin for low and high line conditions — would exceed the family's ratings.

Then I considered a boost topology, as it requires a

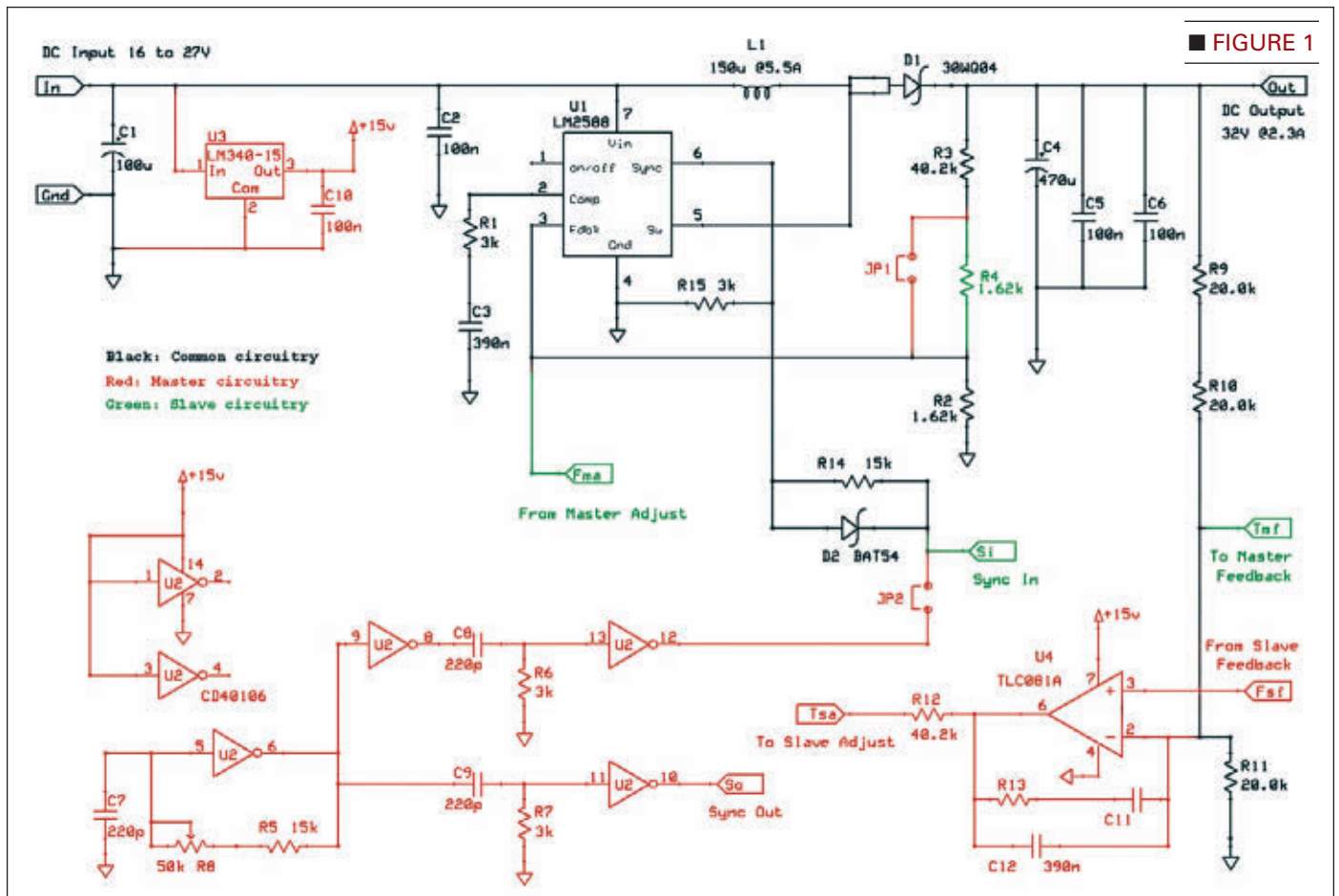
lower voltage input which will be stepped up. The output voltage may be easily realized with an input voltage in the 25 volt whereabouts — easily met with off-the-shelf transformers. Unfortunately, the boost regulators place a substantial current stress on the main transistor switch and I could not get the desired power level (150 watts) with any single IC from National's lineup.

Back to the drawing board. In these circumstances, the solution is frequently to use a boost controller IC coupled to an external MOSFET switch. That would have worked, but I wanted to attempt something different. How about two simple switchers in a master/slave boost configuration? That was intriguing, as I had always desired to test my skills at current sharing schemes. Additionally, since two devices are employed, how about synchronizing them with a 180 degree phase shift, such that we have a two phase controller with half the ripple and a step response twice as fast of a single switcher? The idea became very appealing as the lessons learned from this experiment could be applied later in high power supplies.

Circuit Description

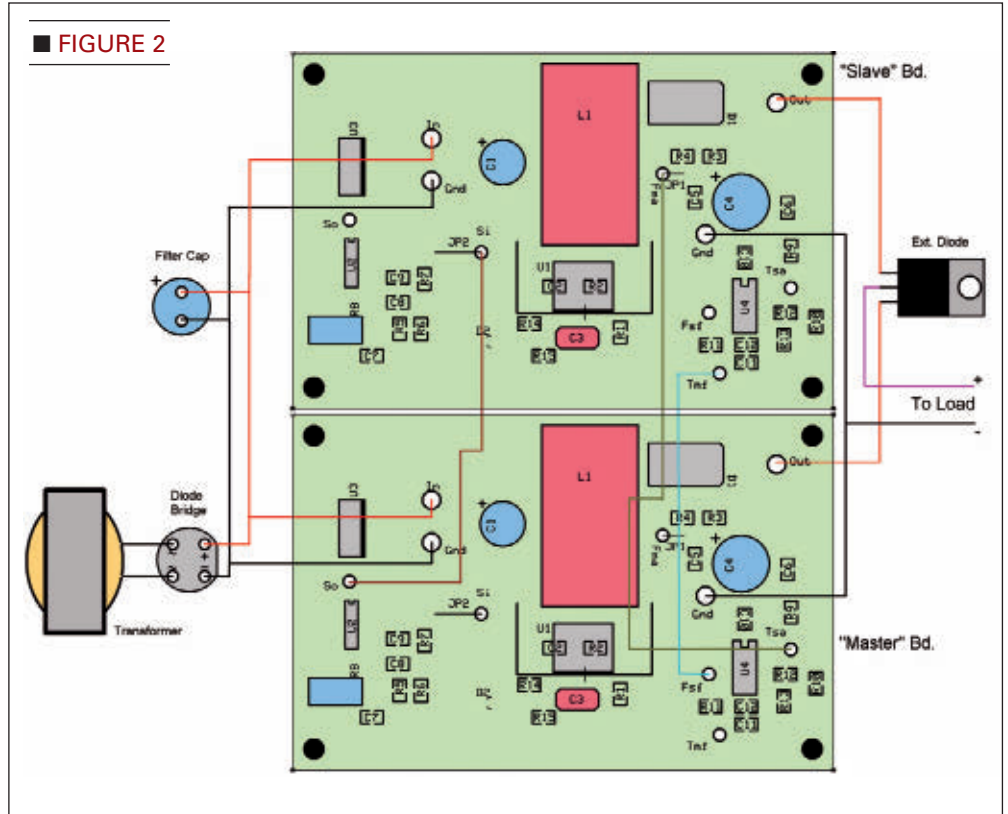
For a high performance switchmode power supply, a printed circuit board (PCB) is a must to accommodate not only large ground planes but also a few strategic components in SMT format. Also, a lot of thought was given to design a single layout that would accommodate either the master or slave configurations, depending on how the board is stuffed.

The result is shown in **Figure 1** which is drawn on



three distinct colors: black for the common circuit components for both configurations; red for the unique components for the master circuit; and green for the unique components for the slave circuit. Therefore, the project consists of two separate boards: one which we will call the master and will contain the black and red components; and the other is a slave with the black and green components. There are some jumper wires between the two boards, as explained next and seen in **Figure 2**.

The selected Simple Switcher device was the LM2588 boost regulator U1. C1 and C2 are input decoupling capacitors. R1 and C3 are loop compensation components calculated by the Simple Switcher software. L1 and D1 are the main boost inductor and



diode. R3 and R2 are the voltage divider that provides DC feedback to establish the output voltage, and C4, C5, and C6 are the output filter capacitors. With the components described so far, one could have a fully functioning power supply block. However, there are some additional components also drawn in black: Voltage divider R9, R10, and R11 will provide voltage feedback for the master/slave tracking; and R14, R15 are a voltage divider which helps to synchronize both. The LM2588 requires a low level at its sync input, which explains the reason for this divider. This will slow down the falling edge, thus the addition of a Schottky diode D2.

The master circuit is comprised of U3, a three terminal

15 volt regulator for the auxiliary circuitry. The other consists of hex Schmitt trigger U2 and op-amp U4. The first section of U2 is a simple oscillator whose frequency is controlled by C7, R8, and R5. This feeds a differentiator C9, R7, and another U2 section working as an inverter. That section also feeds another differentiator C8, R6. The narrow spikes coming from both differentiators are fed to the last U2 sections which by nature of their Schmitt-trigger characteristics output a clean narrow pulse, which can be seen in **Figure 3**. The end result is two, complementary synchronizing pulses. One pulse will couple via jumper JP2 to the master LM2588 in the same board. The other pulse labeled "Sync Out" will connect

via a small jumper cable to the "Sync In" in the slave board and then to the slave LM2588.

Op-amp U4 is the heart of the actual sharing circuit. C12, R13, and C11 are the feedback compensation network, but in this particular application only C12 is employed and the others are left blank. However, if you have access to a network analyzer and desire to optimize the feedback, you can do so with those two locations. Resistors R9, R10, and R11 in its same board are connected to the inverting input and provide the voltage reference. On the slave board, these same resistors are installed but there is no op-amp. Therefore, a jumper wire connects the slave's "To Master Feedback" node to the master's "From Slave Feedback" node together. The opamp's feedback is fed via R12 and "To Slave Adjust" to the "From Master Adjust" node.

This node is the same node that came from resistor divider R2, R3 that sets the voltage. However, as seen again from the schematic, the master board has a jumper connected between the two resistors to complete the divider, whereas the slave board has an additional resistor R4. The end result is that by itself, the slave would attempt to output a higher voltage than the master. But thanks to the feedback coming from the op-amp, its voltage will be reduced to within a few millivolts of the master's and most importantly, it will track any dynamic voltage variations, minute as they are. Thus, we ensure that both supplies will share current equally. Also seen in Figure 2 are additional components external to the board: the main input transformer; rectifier bridge; and filter capacitor, along with the ORing diode. These are located

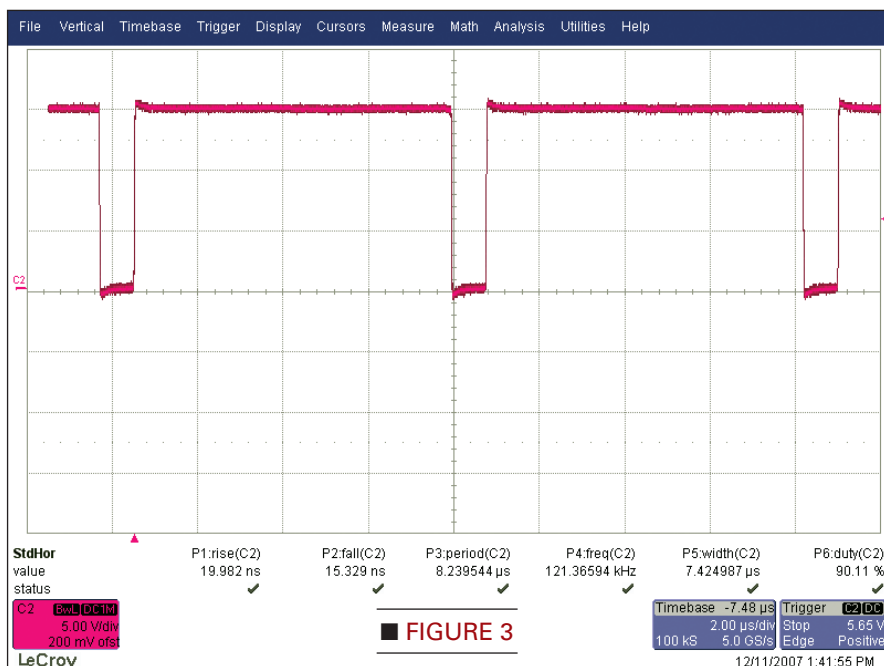


FIGURE 3

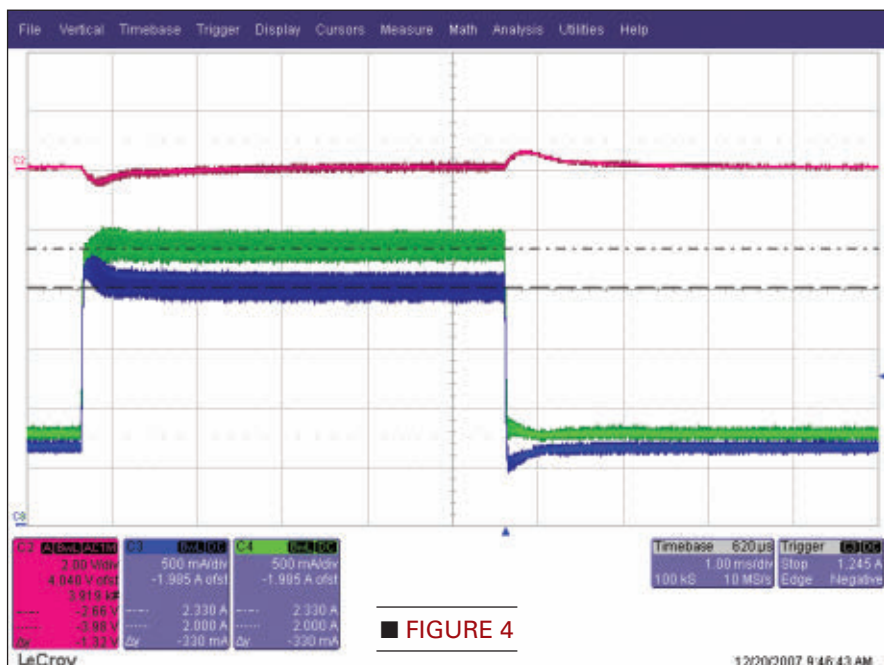


FIGURE 4

externally. Please note that it would be impossible to label the full net names on the board and an acronym must be used instead. For instance: “To Slave Adjust” is replaced with the acronym TSA. This same acronym is used on the schematic itself.

Building the Circuit

The best way to build a switchmode power supply is by employing a proper PCB; an example of this is available on the *Nuts & Volts* website (www.nutsvolts.com). This is a combination SMT/thru-hole board which obtains the key benefits of both.

You'll need a good multimeter that can also read frequency and a power resistor outlined next. An oscilloscope is not strictly necessary but certainly useful in observing the overall performance. A variac is also useful.

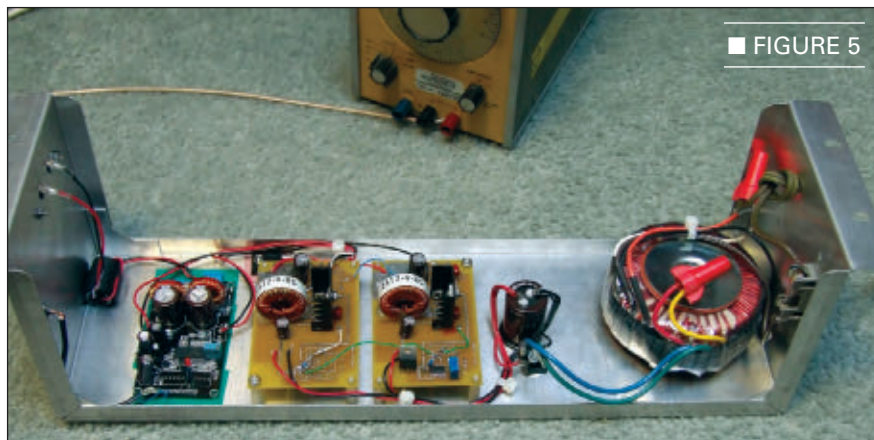
Since SMT devices are involved, a fine-pointed iron, tweezers, and a good magnifying glass are required. This is important as the main reason that a project like this will not work is incorrect soldering.

Please note that there are a few precision 0.1% resistors. These are critical for proper current sharing. An alternative is the more common 1% resistors which could be sorted with a good 4-1/2 digit multimeter. Additionally, ensure that the TLC081 is the “A” suffix version, as it has a

lower offset voltage than the standard part at a cost of a few additional pennies.

The task in assembling this project can be divided into the following milestones:

- 1) Wire the main transformer, rectifier bridge, and filter capacitor. This will be your source. Test it by itself; it will provide approximately 25 volts.
- 2) Solder only all the master components to the master board. All are SMT devices.
- 3) With the subassembly from Step 1, power up the master board, make sure that +15V is present, and that the complementary oscillator sync pulses are present. Adjust R8 for approximately 120 kHz.



PARALLEL THREE-TERMINAL REGULATORS

Adjustable three-terminal regulators have been around for many years due to their versatility, high performance, and simple — almost foolproof — operation. For audio applications, they are ultra-quiet. However, since they dissipate substantial amounts of heat, a high output power level almost always requires paralleling devices.

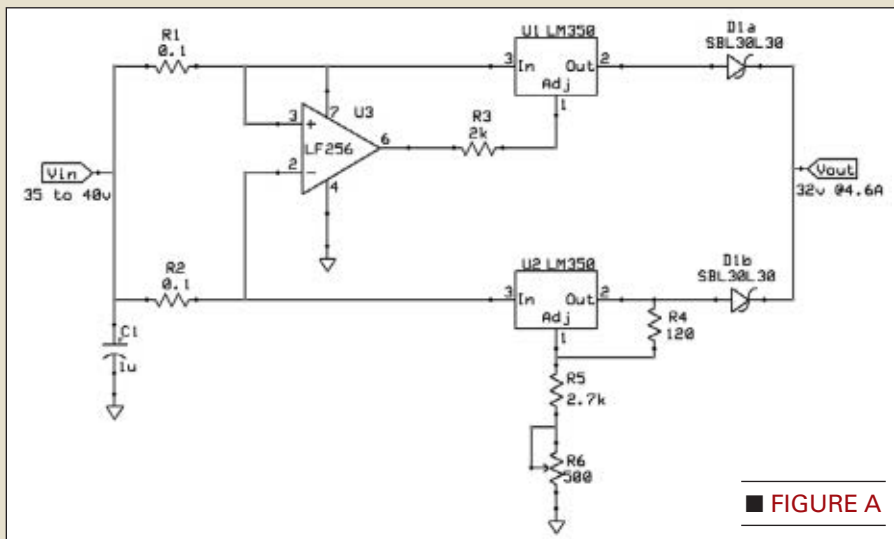
National Semi immediately recognized this fact and designed some circuits to achieve this. The circuit of **Figure A** comes straight out from National's databook, with a couple of changes. First, I learned a while back that diode D1 (which was not required in the app note) is necessary to prevent catastrophic failure in case one of the regulators decides to shut down. This shutdown causes the regulator that has shut down to sink current from the output, often leading to a hard failure. The diode is a dual in a common package, ensuring tight forward voltage tracking.

Secondly, the LM307 op-amp from the original app note has been discontinued. I've used the LF256 successfully as a replacement. Please note that if you decide to employ the cheaper version LF356, its maximum input voltage is eight volts lower and, therefore, both the supply's input and output voltages have to be scaled down

by the same amount.

Being a linear supply, it will dissipate heat — lots of it. Mount U1 and U2 in a large common heatsink such that they track thermally. A fan is necessary, as under worst case conditions the circuit will dissipate close to 40 watts.

Of course, a single LM338 could have been used, but the techniques learned here may also be used to parallel a pair of those devices.



PARTS LIST

COMPONENT	MASTER LOCATION	SLAVE LOCATION	EXTERNAL LOCATION
<input type="checkbox"/> 4,700 μ F, 50V electrolytic	C1	C1	C100
<input type="checkbox"/> 100 μ F, 35V low-Z electrolytic	C2, C5, C6, C10	C2, C5, C6	
<input type="checkbox"/> 0.1 μ F, 50V ceramic 0603	C3, C12	C3	
<input type="checkbox"/> 390 nF, 50V, ceramic 0603	C4	C4	
<input type="checkbox"/> 470 μ F, 50V, low-Z electrolytic	C7, C8, C9		
<input type="checkbox"/> 220 pF, 50V, NPO ceramic 0603	R1, R6, R7, R15	R1, R15	
<input type="checkbox"/> 3K, 5% 0603	R2	R2, R4	
<input type="checkbox"/> 1.62K 1% 0603	R3, R12	R3	
<input type="checkbox"/> 40.2K, 1% 0603	R5, R15	R15	
<input type="checkbox"/> 15K, 5% 0603	R9, R10, R11	R9, R10, R11	
<input type="checkbox"/> 20.0K 0.1% 0603	R8		
<input type="checkbox"/> 50K single turn trimpot			
<input type="checkbox"/> Common cathode dual Schottky SBL30L30, Diodes, Inc.			D101
<input type="checkbox"/> Schottky 30WQ04, Vishay	D1	D1	
<input type="checkbox"/> Schottky BAT54, Diodes, Inc. (www.4starelectronics.com)	D2	D2	
<input type="checkbox"/> Boost controller LM2588, National Semi	U1	U1	
<input type="checkbox"/> Hex Schmitt-trigger CD40106, generic	U2		
<input type="checkbox"/> 15 volt, one amp voltage regulator, LM340-15, generic	U3		
<input type="checkbox"/> Low offset single op-amp TLC081A, Texas Instruments (www.ti.com)	U4		
<input type="checkbox"/> 200 volt, six amp bridge rectifier GBJ601, generic			D100
<input type="checkbox"/> 120/18V, six amp transformer			TR100

4) Solder all the common components on the master board, with the SMT devices first. Please note that a small capacitor is located below U1's legs. Also, U1 should be mounted on its heatsink with proper thermal compound. The heatsink does not require isolation to U1's tab.

5) Connect a 16 ohm, 30 watt resistor to its output. Power up the unit and check the output voltage. Please note: The resistor's actual power rating is over 60 watts, so leave this smaller resistor connected only for a brief moment because it will overheat. Check the output voltage which will be around 32 volts \pm 5% and ripple with the scope.

6) Repeat Steps 4 and 5 for the slave board. Do not connect it to the master board yet. Please note that its output voltage will be about one volt higher than the master.

7) Jumper the two boards together as shown in Figure 2 and add the external ORing diode.

8) Now connect the same power resistor to its shared output and verify that the slave's output voltage is very close (within a few millivolts) to the master's output voltage.

9) You are now ready to connect the power supply to your project!

The scope plot in **Figure 4** shows the circuit's current sharing performance during a dynamic load change — by far, the worst case scenario. This was measured with an electronic load and current probes. It can be seen that the current suddenly jumps from about 1.4 amps to 4.3 amps (the sum of both the blue and green waveforms); the current slew rate for both supplies is identical, with minimal overshoot and undershoot. The current sharing error at 4.3 amps is only 330 milliamps — less than the 10% error target.

Additionally, on the red trace we can see the output voltage behavior during such demanding conditions. It can be seen that the voltage displays a critical damped response without any ringing which would indicate instability.

Lastly, in **Figure 5**, we can see a photo of the assembled project. The master/slave power supply circuit is the two identical boards located towards the middle of the chassis. I used a toroidal input transformer, but that is not necessary. **NV**



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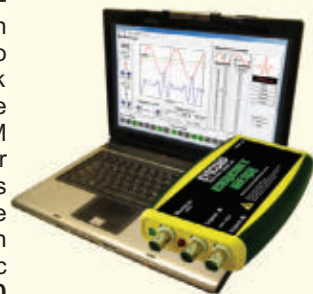
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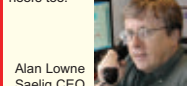
RF & EMF Spectrum Analyzer 1Hz to 7GHz for WiFi, mikes, etc.

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"I really like this scope adapter - it's really meant for teaching electronic experiments but it's ideal for engineers too."



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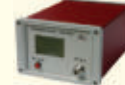
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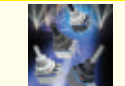
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Analog Mathematics

by Gerard Fonte

In the midst of the digital revolution, it seems that the utility of analog mathematical circuits has been shunted aside. This is not surprising.

Generally, digital computing has many advantages over analog computing. However, in the realm of microcomputers, some of these calculations are not trivial and can sometimes be downright nasty to implement. So, there are still useful and important applications for analog mathematics in today's digital world. In fact, the marriage between analog computing and microprocessors (μ Cs) can be remarkably efficient.

For example, suppose you need to calculate the logarithm of a voltage to stabilize your robot. You could try to perform a direct calculation which would take a lot of time. You could use a look-up table which would use a lot of memory. Alternatively, you could employ some sort of recursive estimation which takes a variable amount of time and fairly complex programming. However, using an op-amp and a transistor you can find the logarithm of your voltage as fast as the op-amp can settle. This article will discuss techniques of analog pre-processing in order to streamline your whole μ C system.

Analog Accuracy, Resolution, and Repeatability

The accuracy of a measurement is how close it matches some standard. That is, if the meter reads 1.000 volts the voltage should really be 1.000 volts, not 1.100 volts. Open-ended analog systems usually have an accuracy of a few percent. This initially seems quite bad. But many μ C analog-to-digital converters (A/D) use the positive power supply for a reference voltage. This supply can easily vary by a few percent. The situation is much worse if batteries are used. If a voltage reference is employed (a device that provides a precisely defined voltage), then analog and digital accuracy can be about the same (for simple μ C systems). However, it is rare for the accuracy of analog systems to be better than about 0.01% (13 bits). More typically, analog accuracies are about 0.1% (10 bits).

Resolution refers to the ability to separate two closely spaced values. Generally, this is defined by the number of digits or bits. An eight-bit A/D has a resolution of $1/256$. So, if the A/D reference is 5.000 volts then each bit is 0.0195 volts (5V divided by 256) or about 20 mV. This is pretty bad. Analog systems have "infinite" resolution. That means that there is nothing inherent to the system that limits the resolution. Obviously, no system has true

"infinite" resolution. Noise and other factors create a practical limit. But this limit can be very tiny. It is not unreasonable to have analog resolution down to 1 ppm (Part Per Million). This corresponds to about 20 bits in a digital system. (This is seen in ordinary audio recordings. Digital systems of 16 bits are the minimum for Hi-Fi playback. Twenty-four bits and higher are now commonplace.)

Repeatability is the big weakness of analog systems and the big strength of digital systems. Unit to unit repeatability is often limited to a few percent for analog systems (without a reference). Worse, over time and temperature an analog circuit can change by many percent. This is generally the result of component value change. Digital systems do not have this problem.

However, there is a problem associated with analog repeatability when multiple stages are used. In this case, the errors are multiplied by the number of stages (or worse). So, if you are cascading analog math circuits, don't expect high precision. This is generally not a problem with digital math because the only error associated with multiple operations is the rounding error of half a LSB (least significant bit). If the word length of the numeric values are large enough (16 to 24 bits), this can generally be ignored.

Associated with repeatability is the consideration of noise. Analog systems are susceptible to many sources of noise at all levels. This causes variations in repeatability. Depending on the circuit, this noise may or may not be an important factor. Digital systems are only concerned with noise when it approaches a significant percent of the bit value. Once digitized, noise is rarely a concern. Digital values can be repeated virtually forever without degradation. Analog values (like tape recordings) show a continuous loss of repeatability every time it is reproduced because noise is added every time. However, this repeatability concern is not really a factor here because we are examining analog pre-processing rather than analog reproduction.

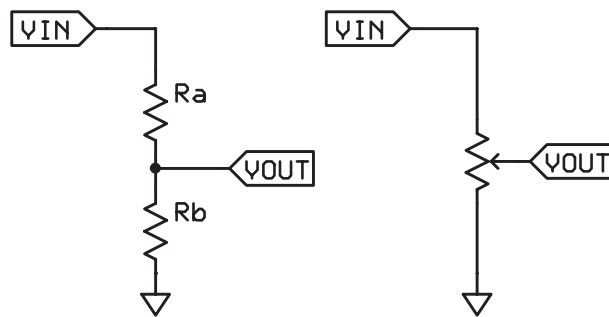
Scaling

The simplest analog pre-processing is converting your analog signal to match your A/D. If your A/D has a range of zero to five volts, it will work best if your input signal is in that range. If your input voltage goes from zero to one volt, then 80% of the A/D's resolution is being wasted. (For convenience and unless otherwise specified, it will be assumed that an eight-bit A/D is available on your μC and that it will operate with an input of zero to five volts and a bit value of 19.5 mV.) This procedure is called scaling. Simple mathematical operations like adding, subtracting, multiplying, and dividing are used.

The simplest scaling problem to solve is when the signal is too large for the A/D. For example, suppose your sensor provides 0 to 10 volts. Here, a simple voltage divider is all that is needed. **Figure 1** shows a typical scaling circuit. However, there are a couple of points to address. Accuracy depends upon the precision of the resistors. Two 1% resistors can yield a worst-case error of 2%. If the desired divider ratio is not simple, it may not be possible to find exact resistor values (your needs may fall between two standard values). Of course, you can always add additional resistors in series or parallel to obtain exactly what you need. A potentiometer can certainly provide the exact ratio, if you are willing to live with the initial setup effort and the possibility of vibration changing the setting. The formula for determining the resistor ratios is: $V_{\text{out}} = V_{\text{in}} * R_b / (R_a + R_b)$.

More importantly – and more subtly – it's important to match the resistance values of the divider to that of the sensor and A/D. Most μCs expect to see a fairly low impedance for the A/D input. Typically, this is about 10K. Thus, your divider resistors should be significantly lower than this or else conversion errors can happen. However, your sensor must be able to provide enough drive for the divider resistors (generally a few mA). (Note that if this is a problem with the divider, it is likely there is a problem when directly connected to the A/D, as well.) For added drive, an op-amp can be used to buffer the signal as shown in **Figure 2**. This allows large resistance values to be used for the divider.

Once an op-amp is added, more considerations are necessary. The first is that the input and output range of the op-amp must match the range of the sensor and A/D. Modern rail-to-rail op-amps can come to within one or two bits of zero and V_{CC} . Normally, this is adequate. Older op-amps may not accept an input value within a volt or so of V_{CC} (most can accept an input voltage of zero volts) so the maximum input value is reduced. Their output voltages require substantial headroom for both V_{CC} and ground. For example, consider the popular LM741 op-amp. Its output can't come closer than two volts to either voltage rail. The LM324's output can go to as low as 20 mV, but can't come closer than three volts to V_{CC} . So, if you are using an LM324 at five volts, the input range is zero to three volts and the output is 0.02 to two volts. (Note this illustrates one of the many reasons why the LM741 and



■ **FIGURE 1.** A simple voltage divider can be made up of two resistors or a potentiometer. The voltage out is equal to $V_{\text{in}} * R_b / (R_a + R_b)$.

LM324 should never be used for serious work.)

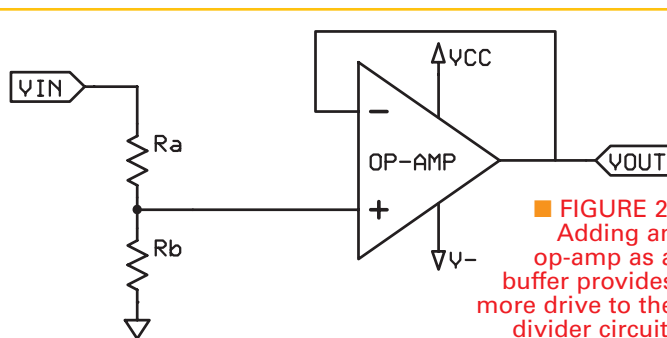
A separate power supply for the op-amp is always useful because it allows you to compensate for headroom problems. Additionally, it can reduce noise that may come from the digital switching in the μC .

Figure 3 shows a simple method to isolate the op-amp power from the μC power.

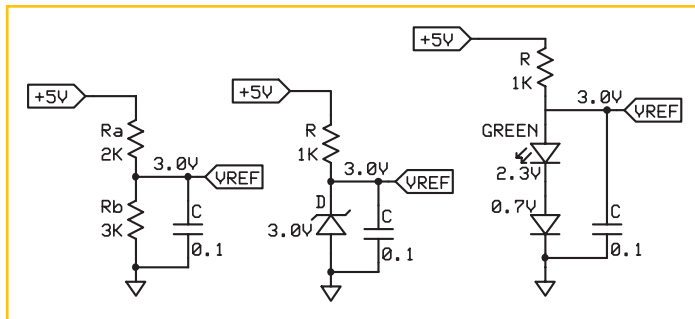
All of this may seem to be adding more project difficulty than removing it. Proper circuit design demands attention to detail. Examining all the aspects of a circuit is critical for the proper operation of that circuit. It is important to understand the implications of a circuit before implementing it. For example, you know that most μC A/D converters use V_{CC} as the reference voltage, didn't you? And that typical three-terminal voltage regulators are accurate to only $\pm 5\%$. The point is that all the strong and weak issues must be analyzed before you start soldering things together. If you are not familiar with op-amps, it is necessary to explain these points before continuing. This is somewhat similar to examining power-on-reset for a μC before starting a project. There will be no further discussion of op-amp requirements.

Multiplication

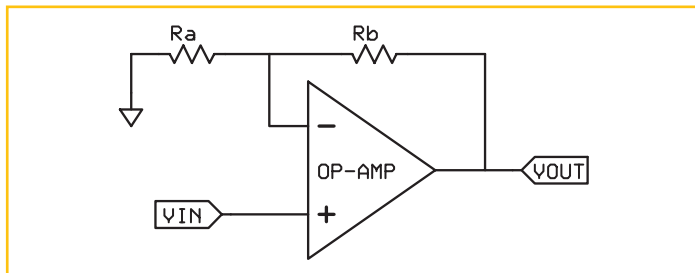
Making a signal smaller is easy. But how do you make a signal larger if your input signal is only a *little* smaller than ideal, say 0 to 3.0 volts instead of 0 to 5.0 volts? There is a very easy method that is available on most μCs . Simply use a lower external voltage reference. **Figure 4** shows some methods of doing this. The value returned by the A/D is the ratio of the input signal to the reference (or



■ **FIGURE 2.** Adding an op-amp as a buffer provides more drive to the divider circuit.



■ **FIGURE 4.** Supplying a reference voltage less than V_{cc} can be done in a number of ways. The best use diodes for better stability. Other methods are also possible.



■ **FIGURE 5.** A typical non-inverting op-amp. The gain, or multiplication, is defined as: $V_{out} = V_{in} * (R_a + R_b) / R_a$.

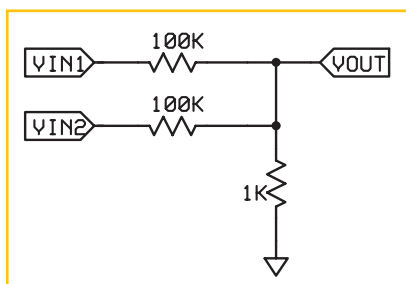
input divided by reference). So, if the reference is changed to three volts (instead of V_{cc} which is five volts), you will be able to use the full range of the A/D. You will need to check on the reference specifications of your particular A/D to see how low you can go. Ideally, you want the reference to equal the maximum input signal.

Note that generally A/D converters are tolerant of input voltages higher than the reference. They usually return a maximum value but are not damaged. However, virtually all A/Ds can be damaged by input voltages higher than V_{cc} . Using a lower reference voltage provides some safety margin should the input be larger than expected.

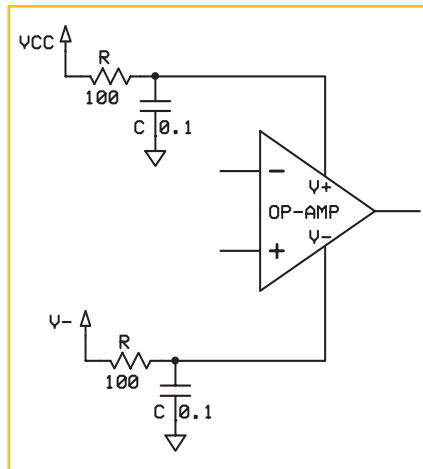
If your input is very small, you will need to add a gain circuit which multiplies the signal by some factor.

Figure 5 shows a typical non-inverting op-amp gain stage. The formula for finding the resistor ratios is: $V_{out} = V_{in} (R_a + R_b) / R_a$. High resistor ratios (megohms) can result in noise problems. Low resistor values (100s of ohms) will cause relatively high current consumption. Gain stages of 1,000 to 10,000 are reasonable if the frequencies are low. For higher frequencies, multiple

■ **FIGURE 6.** Voltage summing is simple. Just be sure that the resistor connected to ground is much less than the input resistors so that it will not limit the current. The input resistors do not have to be the same. If they are different, the voltages will sum proportionately. Note that the output is also divided by the resistor to ground.



the voltages will sum proportionately. Note that the output is also divided by the resistor to ground.



■ **FIGURE 3.** Isolating and filtering the power supplies reduces noise to the op-amp. If the op-amp negative supply is ground, then the V_{-} components should be eliminated and the op-amp V_{-} pin should be connected directly to ground.

stages will be required because the slew rate (a.k.a., gain

bandwidth product) of a single amplifier will be exceeded.

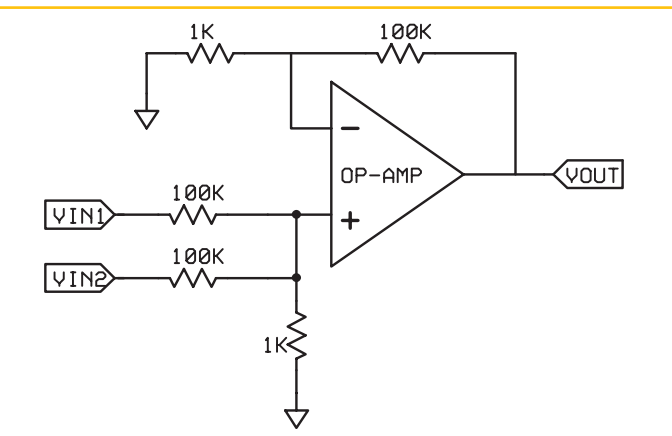
Addition/Offset

Adding or subtracting a voltage from your sensor is not too difficult. Let's assume your sensor produces an AC wave of ± 2.5 volts and you want to see zero to five volts. Basically, you want to add 2.5 volts to the signal so that it will always be positive.

You can sort of do that with just resistors as shown in **Figure 6**. The result will be positive but not zero to five volts. R_{sum} collects all the currents coming from the other resistors and converts it to a voltage. Therefore, R_{sum} must be much lower than the other resistors so that it will not limit the current and give poor results. Typically, R_{sum} is about 1% of the other resistors. The second point is that the circuit acts as a voltage divider, as well as a summer. So as diagramed, the output will be about 1% of the input.

The input resistors do not have to be the same. If they are different, the lower-valued input resistor will have a proportionally larger effect on the sum. To determine any individual resistor ratio (see voltage dividers above to calculate the actual voltage), assume all the other input resistors are disconnected.

■ **FIGURE 7.** By adding a gain stage after the resistor summer, the output can be scaled properly. The op-amp gain setting resistors can be the same ratio as the summing resistors. Many other variations are possible.



The incorrect output voltage can be fixed by adding a gain stage as shown in **Figure 7**. The output is the algebraic sum of the two (or more) inputs. Conveniently, the resistor ratios for the feedback circuit are the same as the individual voltage dividers (in this case, 100:1). Different feedback resistor values can be used as long as the ratios are the same. As shown, the $\pm 2.5\text{V}$ signal has been shifted by +2.5 volts so the output is zero to five volts.

You can, of course, use different feedback resistors and the output will be changed accordingly. This is seen as an overall scale factor change or: $V_{out} = (V_{in1} + V_{in2}) * \text{gain}$. If you used different values for the input summing resistors, you will have to take that into consideration, as well. This is seen as a multiplication/division of an individual input according to the difference in the current supplied to the summing resistor. As you can see, very complicated relationships can be created.

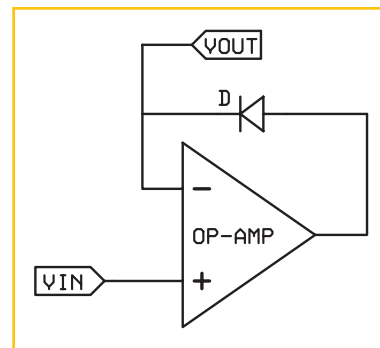
Absolute Value/Rectification

Another way to eliminate the problem of negative input voltages is to simply remove them. The mathematical term rectification is generally associated with removing negative parts of a signal. This can be accomplished with a diode connected in series with the input signal. It's a quick and dirty solution that also eliminates a positive portion of the signal, as well. Because of the forward voltage drop associated with diodes (typically 0.7 volts), the diode strips off 0.7 volts of the positive part of the signal, as well. This may or may not be a problem. (Losing the bottom 0.7 volts of a signal is equivalent to losing 3.5 bits of resolution in our eight-bit A/D.)

A precision rectifier (**Figure 8**) puts the diode in the feedback loop of an op-amp. The result is that the 0.7 volt diode drop is eliminated. The whole positive part of the input signal is passed. You should include a negative supply for the op-amp because you should never apply an input signal that is below the negative rail. That being said, most op-amps have protective clamping diodes at the inputs to prevent damage and latch-up from negative voltages. So, if the current is kept very low ($< 1 \text{ mA}$) there is *usually* no problem for hobbyist-type applications. (Look at the datasheet to verify that there are protective diodes.)

Full-wave rectification is mathematically known as the absolute value of the input signal. You can get the absolute value of an AC signal by applying it to a full-wave rectifier. This is done all the time with power supplies. There is still the problem of the voltage drop associated with the diodes, though. Worse, the signal

■ **FIGURE 8.** A simple precision half-wave rectifier puts the diode in the feedback loop. That eliminates the 0.7 volt forward voltage drop seen with a bare diode. The circuit will properly rectify millivolt signals (or less).

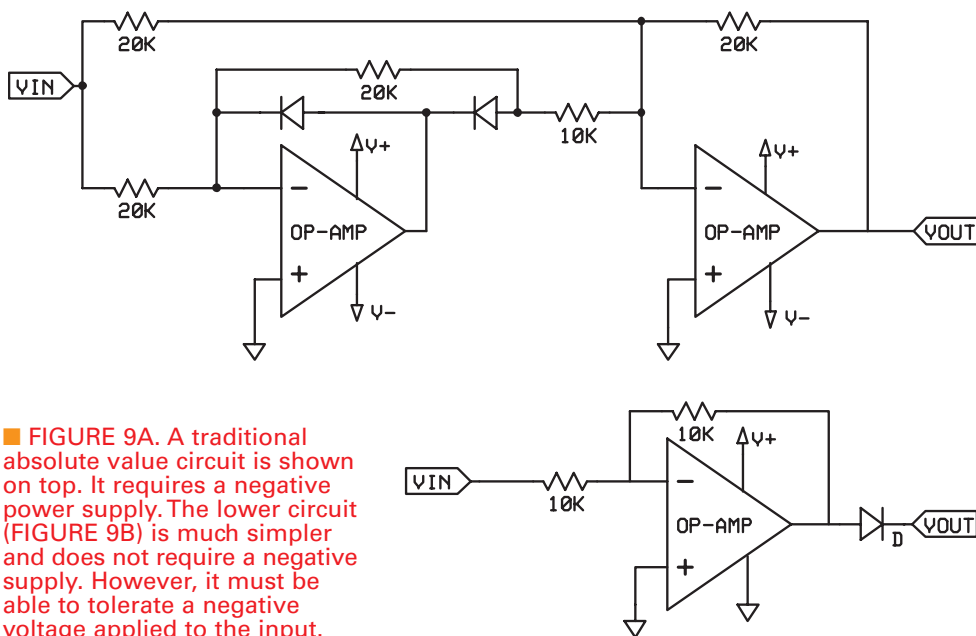


passes through two diodes, so the signal ± 1.4 volts around ground is lost. A typical absolute value circuit is shown in **Figure 9A**. This eliminates the voltage drop problem associated with the diodes. Note that a negative power supply is required for this circuit.

Some op-amps — like the LMC6282 and family — are designed to allow a negative voltage to be applied to an input as long as it is current limited. This can be used to simplify the absolute value circuit and eliminate the need of a negative supply voltage. **Figure 9B** shows this circuit. Note that the input signal and op-amp output are actually joined at the output. When the op-amp is outputting a positive half-cycle, it overwhelms the input portion. When the op-amp output is “off” (because of the reversed-biased diode), the input half-cycle signal passes through the two resistors to the output. This means that the half-cycles have different drive capabilities: high drive from the op-amp and low drive from the input (through the resistors). Therefore, this circuit must be connected to a high impedance load to maintain proper half-cycle amplitudes. Alternatively, it can be buffered with another op-amp.

Integration and Differentiation

Fundamentally, integration is usually not much more



■ **FIGURE 9A.** A traditional absolute value circuit is shown on top. It requires a negative power supply. The lower circuit (FIGURE 9B) is much simpler and does not require a negative supply. However, it must be able to tolerate a negative voltage applied to the input.

than applying the signal to a capacitor.

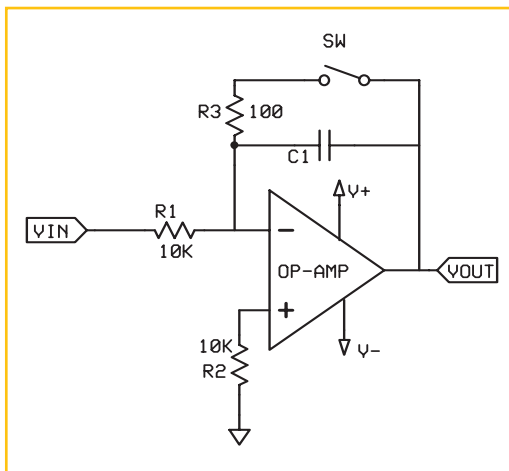
Figure 10 shows a typical integrator.

The switch (which can certainly be electronic — like an FET) removes the charge on the capacitor before the integration function starts. Resistor R3 limits the current through the switch during capacitor discharge and is especially necessary for electronic switches. As shown, the output of the circuit will be the sum of the voltage applied to the input times the length of time applied, times $1/R_1C$. (R_1 is the resistor value in ohms and C is the capacitor value in farads.) Use a quality capacitor with low leakage and low dielectric absorption. It is also important to keep R_1 and R_2 the same so that the bias currents are the same. Otherwise, the output can drift considerably, especially over temperature. The circuit works best with high input resistance op-amps ($>$ teraohm). This circuit can also be characterized as a low pass filter with a corner frequency of 0 Hz.

There are a couple of points to ponder. If the input signal is removed or set to zero, the output voltage remains unchanged. This makes sense when you stop to think about it. Adding a lot of zeros to a sum doesn't change the sum. In order to reduce the output, a negative voltage must be applied (and a negative power supply should be used for the op-amp, as well).

A reverse or inverted integrator can be created by applying the signal to the inverting input of the op-amp. In this way, a positive input signal will decrease the output. Note that the capacitor must be charged up for this to work, so the switch has to be changed (or better, a signal applied to the non-inverting input to charge the capacitor).

A differentiator is also fairly easy to implement in theory, as shown in **Figure 11A**. However, there are problems. This circuit can be characterized as a high pass filter with the corner frequency at 0 Hz and a positive slope of 6 dB per octave. As such, noise can be a significant problem leading to instability (oscillation) and degraded performance. For that reason, an added RC network (R_3 , C_2) is used to reduce the gain at high frequencies (see **Figure 11B**). The output of the circuit is the input times R_1C_1 times d/dt . An inverted function can be obtained by applying the



■ **FIGURE 10.** An integrator is easy to implement. The switch is necessary to remove the charge on the capacitor (the resistor limits the discharge current). An electronic switch such as an FET can also be used.

signal to the inverting input resistor and grounding the non-inverting input (as with the integrator above).

Proportional-Integral-Derivative Controller

Now that you know how to sum, multiply, integrate, and differentiate, you can combine them into a PID (Proportional

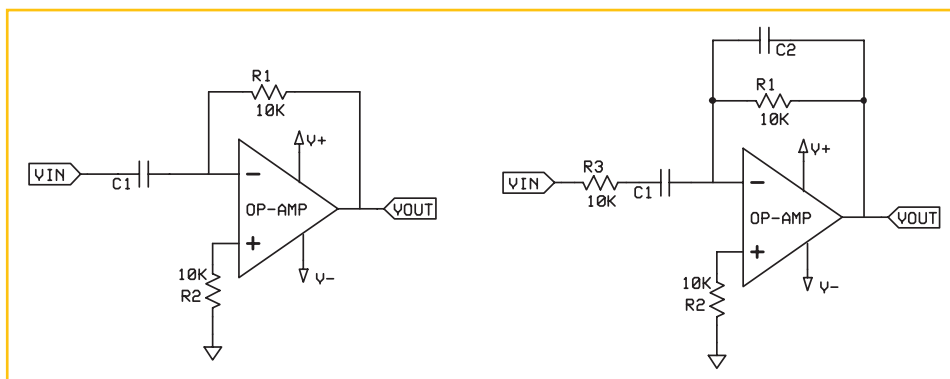
Integral Derivative) controller. As you can see, it only takes a few parts to create a very sophisticated analog calculator. Analog PIDs can be very fast — as fast as the op-amps and settling times of the capacitors. Often, this is much faster than the μ Cs. Obviously, the big drawback with the analog system is that it can't be changed easily. Plus, there is always the concern about component value drift, especially over temperature. Nevertheless, analog PIDs have been around for decades and can be very effective.

X-Y Multiplication

Previously, we examined multiplication of a value by a constant but suppose you want to multiply two different values together. This is very different. We'll look at a simple method that is easy to implement. There are more precise and complex circuits that can be built with op-amps, but it makes little sense to do so when you can buy a chip that does it all very cheaply. Analog multipliers/dividers are available for a few dollars. (For example, Analog Devices AD633 costs \$7.75 at Jameco. Note that most commercial analog "multipliers" allow you to square and take the square root of a value, too.)

There are three things to mention. The first is about proper sign management. There are four possible combinations of signs (or quadrants) when combining two numbers: $+X +Y$, $+X -Y$, $-X +Y$, and $-X -Y$. The output should provide the proper sign. Not all circuits perform full "four quadrant" calculations. Often, this is not a circuit

necessity. Most often — but not always — the magnitude of the result is correct. The second issue is that the terms multiplication and division often seem to be interchanged. This is because the division by a number greater than one can be represented by the multiplication of a number less than



■ **FIGURE 11A.** A theoretical differentiator uses only a resistor and capacitor. A more practical version (**FIGURE 11B**) uses an extra resistor and capacitor for stability.

one. **Figure 12** is an example of a “multiplier” circuit. From the point of view of two fractional numbers, this is true. However, the result is always smaller than the original values so the concept of division is also true. As shown, the output of **Figure 12** is the fractional product of the two resistive dividers times the input voltage.

The last issue is that many circuits are not scaled for proper output. Their outputs are proportional to the function specified. Like the simple resistor summing circuit mentioned much earlier, the output is not the true sum of the inputs unless additional scaling operations are employed.

Multiplication

A simple way of multiplying two numbers is to create a variable gain amplifier. This can be accomplished by simply making the feedback resistor changeable. **Figure 13A** illustrates this. The output is the input multiplied by the gain of the amplifier which is $(R_A + R_B)/R_A$. If your sensor is a variable resistor of some type (like a thermistor), the circuit can be used as-is. If you have a voltage for V_{IN2} , then you can use an FET instead (**Figure 13B**). Note that the multiplication is not exactly linear because doubling R_B does not exactly double the gain. There are many variations on this theme of gain changing for multiplication. Using a photocell instead of an FET is also practical. *Important note: The leads to the variable resistor are inside the feedback loop of the op-amp and are extremely susceptible to noise and can easily cause op-amp oscillation. The leads must not be longer than a couple of inches.*

Logs and Antilogs

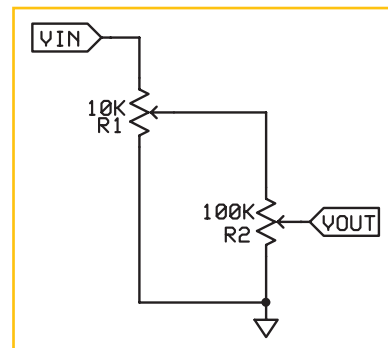
Most higher function analog mathematics incorporate a log/antilog circuit. This allows you to multiply/divide and exponentiate easily. The procedure is to take the log of the value, perform simple addition/subtraction and/or multiplication/division, and then take the antilog. With this method, adding and subtracting is equivalent to multiplying and dividing. Multiplying and dividing becomes equivalent to raising to a power or extracting a root. So, taking the 3.5th root of a number can be accomplished by taking the log of the number, dividing by 3.5, and taking the antilog of that result.

There is a logarithmic relationship between the emitter base voltage of most silicon transistors. In theory, this allows a simple method to generate logs and antilogs.

Figure 14A shows a simple log generator with the measured results. For every factor of 10 increase in the input, there is a “constant” increase of about 55 mV in the output. The error is about 10%. This is not great accuracy, but for feedback systems this may be perfectly adequate. Additionally,

■ **FIGURE 13A.** Multiplication can be accomplished by changing the gain of the circuit with a variable resistor. **FIGURE 13B** does the same thing with an FET that changes its resistance according to the voltage applied to the gate.

■ **FIGURE 12.** Two voltage dividers end up being called a multiplier because multiplying fractions can be the same as dividing by values greater than one.



the circuit is quite temperature-sensitive, changing about 0.3% per degree C. (The capacitor helps to stabilize the op-amp and the diode protects the transistor from excessive reverse current from the op-amp. Neither is probably absolutely necessary.) Some of this error can be eliminated by a self-calibration routine in software.

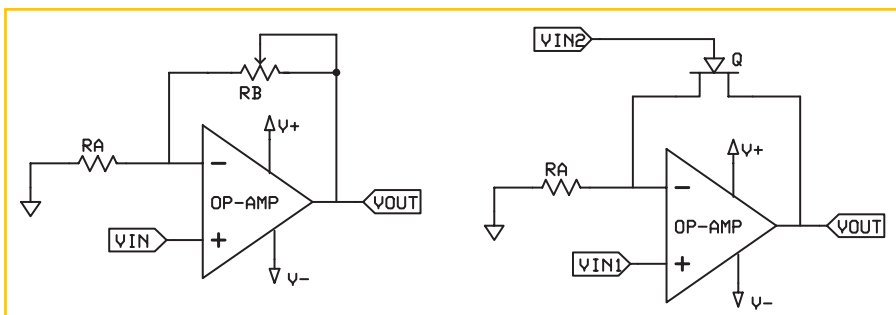
The antilog circuit shown in **Figure 14B** should work but requires considerable effort. It probably isn't practical. However, it has been reported that with the proper matching of transistors, a log/antilog circuit (connecting **Figures 14A** and **14B** in series) provided reasonable results.

More complex and much more accurate log/antilog circuits can be constructed. Typically, these consist of a couple of op-amps, a half dozen resistors, two transistors, and a special temperature-compensating resistor. The accuracy of these circuits can be very good – about 1% over six to seven decades of operation. However, in practice, these are probably too complex for typical μC applications. (See **References** for further reading.)

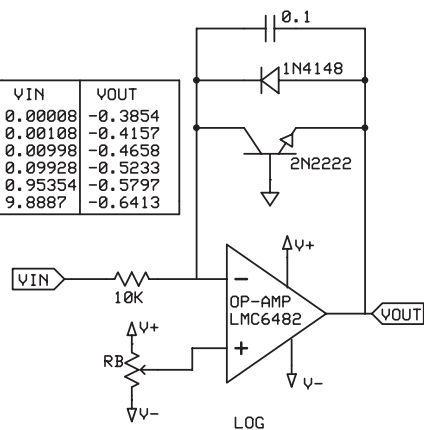
The charging of a capacitor through a resistor also follows an exponential relationship (power of two rather than a power of 10). For every one time constant, the capacitor voltage moves about 63% from where it is towards the supply voltage. I am not aware of any circuit that uses this characteristic for mathematical operation, however it could be useful. (Apply a voltage for a fixed time to a resistor/capacitor network and measure the voltage through the μC 's A/D.)

References

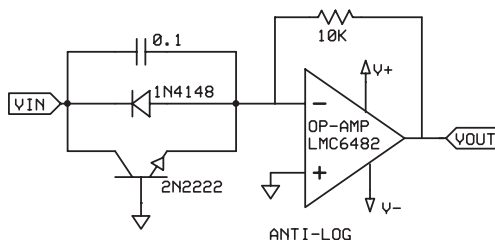
- National Semiconductor Application Notes: AN-4, AN-20, AN-30 (log converters), AN31, LMC6482 datasheet.
- Signetics: “Operational Amplifiers.”
- Analog Devices: Analog Multipliers/Dividers (various datasheets).
- Forrest Mims: January 1979, February 1979, *Popular Electronics*.



VIN	VOUT
0.00008	-0.3854
0.00108	-0.4157
0.00998	-0.4658
0.09928	-0.5233
0.95354	-0.5797
9.8887	-0.6413



■ FIGURE 14A. The log circuit on the left is simple and works reasonably well. Actual measures are provided. The anti-log circuit (FIGURE 14B) provided poor results, although others have reported better performance.



Conclusion

Analog mathematics can be added to your microcontroller system to streamline your design and make it more efficient. Whether it's simple scaling or complicated functions, there are many basic circuits that can assist in calculations. This removes some of the burden from your code and can speed up your whole system. (Note that all circuits were built and tested using an National Semiconductor LMC6484 op-amp.) **NV**

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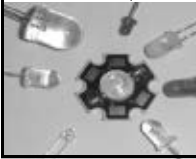


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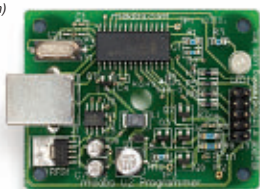
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* As published in EPE Magazine August 2008



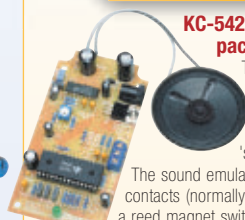
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- 12V automotive ignition coil and case not included
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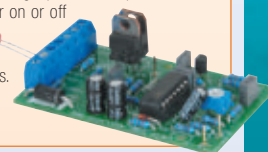


NEON TUBE SOUND DISPLAY KIT

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Following the tremendous success of the original 1997 Sound Mod kit, this latest version overcomes some of the original's limitations. With this latest kit you can now use any output from your car stereo - it is not limited to being exclusively driven by a subwoofer output, unlike its predecessor. This kit drives any colour neon tube in the Jaycar range (see website) and has the option of turning the tube either on or off to the beat of the music. Kit supplied with PCB plus all specified electronic components.

- Requires 12VDC



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- 8 pages



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AVR MICROCONTROLLER: C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

PART 10: Moving Beyond Arduino

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Joe's book & kits are available in our
webstore at www.nutsvolts.com

Last month, we were introduced to the Arduino and made an LED blink. I'm betting that many of you went off to the Arduino website and played around with other examples. So, you've seen The Arduino Way and are now ready to move up to a more advanced 'Way.' This month, we learn how to convert Arduino programs into regular C programs that can be used with the Atmel official software: AVRStudio and the semi-official WinAVR and AVRdude. [Note that in the month since our last episode: Arduino moved from version 12 to version 13, and the Duemilanove now uses the ATmega328 — 16K more memory at no additional charge — yeah! There is information at the end of this article on how you can get your very own Arduino Duemilanove and a special components kit for this and future Smiley's Workshop projects.]

Arduino is a combination of ingredients: a hardware platform, a simplified programming language based on C, a PC side IDE (Integrated Development Environment), a set of libraries to ease the use of the hardware, an online community, AND it is all open source. These ingredients lead to a Way of doing things — The Arduino Way that was created for designers (artists) and is excellent for total novices to get started. I want to take the Arduino to the next step, however, to use it as a basis for learning the

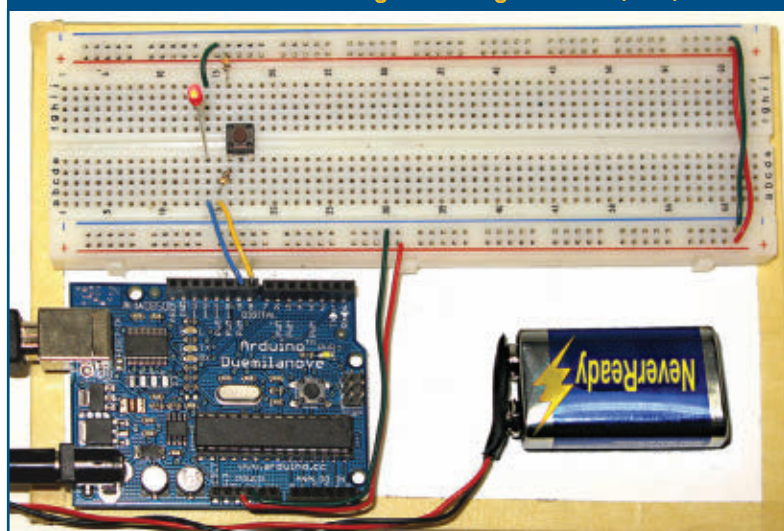
IMHO 'real' C programming language and understanding the AVR hardware. So, let's move from The Arduino Way (TAW) to A C Way (ACW) and use some of the more standard tools like those discussed in Workshops 1 to 8. Our first task will be to convert that TAW Blink example program shown in last month's workshop to ACW.

If you want to build the base shown in **Figure 1** and a box to carry it around in, see Supplement 1 for this workshop: The Arduino Workshop ATmega Learning Platform.pdf which is available on the *Nuts & Volts* website (www.nutsvolts.com).

Arduino to ATmega168/328 Pin Mapping

Before we convert the code from TAW to ACW, let's take a brief look at how the Arduino names the ATmega168/328 pins. This will come in real handy when we want to start thinking about hardware designs using ACW. I/O pin naming is one of the things that Arduino does that is a bit different from what we've seen so far. It considers the 14 digital input/output pins as individuals rather than one of eight pins in a port. For instance, as shown in **Figure 2** (modified from the Arduino website) and **Figure 3**, the Arduino pin 9 is the same as the ATmega328 PortB pin 1 (PB1).

■ FIGURE 1. The ATmega Learning Platform (ALP).

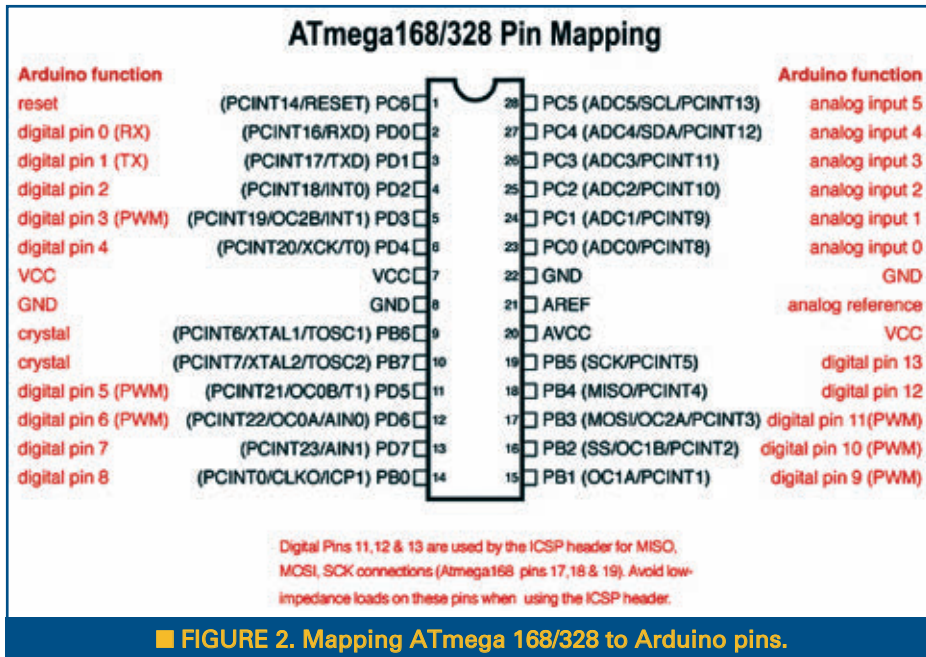


Converting the Arduino Blink Example to AVRStudio

We are going to copy the Arduino Blink example to AVRStudio and run it with only a few minor modifications. Last month, we did this example using Arduino pin 13; this month, we will change it to pin 9 so that we can reuse the hardware for a later example.

Before getting started with the code, wire up the ALP with both an LED and pushbutton as shown in the schematic and photo of the layout (**Figures 1, 10, and 11**). We will use the LED now and the pushbutton later.

If you've been following the Workshop, you may have noticed that the Arduino Blink.c program didn't have the main() function required



■ FIGURE 2. Mapping ATmega 168/328 to Arduino pins.



to show us how to move Arduino examples to AVRStudio (TAW to ACW). Later when we write our own libraries to duplicate the Arduino built-in functions, we will not allow

by C programs. This is one of the simplifications that Arduino takes care of for you (it hides main() in another module). Let's do this cookbook style:

- Create new directory C:\ArduinoToAVRStudio-Blink.
- Copy the core Arduino .c and .h files to the Blink directory from the Arduino-0013\hardware\cores\Arduino\ directory. (No need to copy the .cpp files.)
- Open AVRStudio and create new project 'Blink' in C:\ArduinoToAVRStudio-Blink (where you copied the Arduino files). Creating AVRStudio projects is described in Workshop 2. Be sure and select the ATmega328p.
- Add the Arduino .c and .h files to the AVRStudio project: In the AVRStudio AVR GCC window as shown in **Figure 4**, click on 'Add Existing Source' and then select the files shown in **Figure 5**. Repeat this process for the header files (also shown in Figure 5).
- Open the Arduino IDE [details in last month's Workshop].
- In the Arduino IDE, open 'File/Sketchbook/Examples/Digital/Blink.'
- Copy the Arduino Blink example and paste it to Blink.c in AVRStudio.
- Add #include "wiring.h" to the top of Blink.c.
- Add the main() function shown below to the file.
- Open the wiring.c module and add to the top of the file: #define F_CPU 16000000L.
- The AVRStudio project is available in the Workshop10.zip file, (on the Nuts & Volts website).
- Click the AVRStudio compile button.

You will note that you get about 31 warnings and though I never ignore warnings, in this and only this case I will ignore them, because the compiled code works and the only purpose of this exercise is

warnings to pass unheeded.

```
#include "wiring.h"

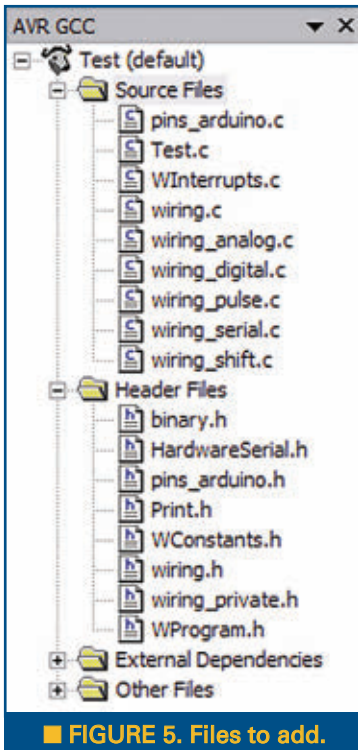
int main(void)
{
    init();
    setup();
    for (;;)
        loop();

    return 0;
}

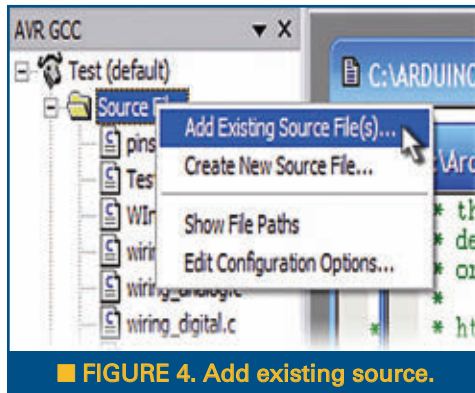
/*
 * Blink
 *
 * The basic Arduino example.
 * Turns on an LED for one second,
 * then off for one second, and so on...
 * We use pin 13 because, depending on your
 * Arduino board, it has either a built-in
 * LED or a built-in resistor so that you
 * need only an LED.
 * [JP 3/15/09 - changed to pin 9]
 *
 * http://www.arduino.cc/en/Tutorial/Blink
 */
// LED connected to digital pin 9
int ledPin = 9;

// run once, when the sketch starts
void setup()
{
    // sets the digital pin as output
    pinMode(ledPin, OUTPUT);
}

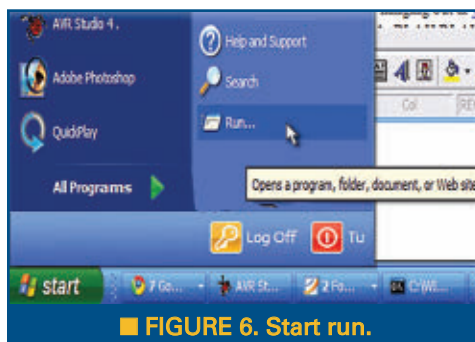
// run over and over again
void loop()
{
    // sets the LED on
    digitalWrite(ledPin, HIGH);
}
```



■ FIGURE 5. Files to add.



■ FIGURE 4. Add existing source.



■ FIGURE 6. Start run.

you are to have any hope of figuring out what happened, you're going to have to get friendly with AVRdude. Well, that's not quite correct ... you can post questions on the Arduino forum and maybe get help figuring out what happened, but eventually, to really understand what is going on, you are going to have to learn to use AVRdude. And while that would be a good topic for at least one full Workshop, let me just provide an introduction with a cookbook approach and also recommend that if you are really interested, you can find the AVRdude manual in your WinAVR directory under `..\doc\avrdude\avrdude.pdf`. For now, just follow the recipe:

- Go to the Windows Start Button and click on Run, as shown in **Figure 6**.
- Open: `cmd`, as shown in **Figure 7**.
- You will see the window shown in **Figure 8**. (If you are a golden oldie, you might say: "Hey, that looks like DOS!" And it sort of is, but not exactly, so be cautious with the nostalgia.)

```
delay(1000); // waits for a second

// sets the LED off
digitalWrite(ledPin, LOW);
delay(1000); // waits for a second
}
```

Uploading with AVRdude

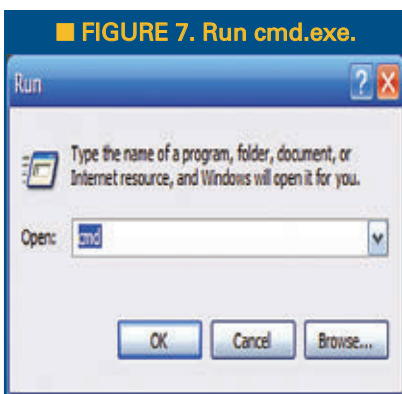
As we saw last month, the Arduino IDE has an upload button that transparently uses AVRdude to send the hex code to the Arduino board. It does this by calling AVRdude with a script that has all the hard stuff written

out for you. That is great if there are no errors — which there probably won't be when you are doing any of the Arduino example projects. But if there is a problem, you get some bright red text in the serial window at the bottom of the Arduino IDE, and if

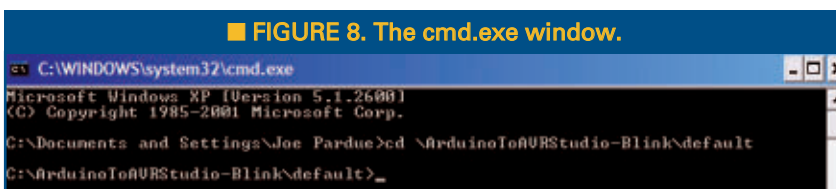
- After the `'C:\Documents and Settings\YOUR NAME` (and, of course, YOUR NAME will be whatever you've set it to be and almost certainly not Joe Pardue as in **Figure 8**), type `'CD \ArduinoToAVRStudio-Blink\default'` to change the directory. Then, click enter so that you are now 'in' the default directory along with `Blink.hex`.
- Open Notepad or Word or some such program and type:

```
avrdude -p m328p -c avrisp -P com6 -b 57600 -F
-U flash:w:Blink.hex
```

- Copy this line and paste it following the `>` in the cmd window as shown in **Figure 9**: AVRdude Upload. (The reason I recommend typing this in something like Notepad is that I had to correct it four times due to typos, and it is far easier to correct it in Notepad than have to correct it in the cmd window.)
- Note that this line assumes that your Arduino is sitting on com6. If you don't know how to find the com port it is using, then see: Smiley's Workshop 10: Supplement 2 — What Serial Port am I using? in the downloads.
- Finally, get ready to click the enter key and start AVRdude. However, the microsecond before you click enter, push the reset button on the Arduino. The Arduino will reset and look for communication from AVRdude which (because you clicked enter on the PC immediately after you clicked reset on the Arduino) will try to communicate with the Arduino. If you get your timing wrong, however, the Arduino board will tire of waiting and jump from the bootloader to the application program. If you did get it right, you will see the text shown in **Figure 9**.



■ FIGURE 7. Run cmd.exe.



■ FIGURE 8. The cmd.exe window.

- Note that AVRdude ends with “avrdude done. Thank You.” Now that is class! Especially for a free program, so go to their website and donate something!

Press the Arduino reset button and pin 9 should blink once per second. We have now done the Blink example TAW last month and converted it to ACW this month.

Next, we will start doing some hardware projects that let us convert more of the Arduino examples from TAW to ACW.

Debouncing a Pushbutton

Converting the Arduino Debounce example to C for AVRStudio is much like converting the Blink example, but I want to repeat the steps – condensed a bit – to help reinforce the conversion process:

- Create new directory C:\ArduinoToAVRStudio-Debounce.
- Copy the core Arduino files to our Debounce directory from the Arduino-0013\hardware\cores\Arduino\ directory.
- Create new AVRStudio project Debounce in C:\ArduinoToAVRStudio-Debounce.
- Copy the Arduino Debounce example to Debounce.c in AVRStudio.
- Change the inPin from 7 to 8:
`int inPin = 8; // number of the input pin`
- Change the outPin from 13 to 9 and outPin from:
`int outPin = 9; // number of the output pin`
- Add #include “wiring.h” to the top of the file.
- Add the main() program shown in the Blink source code above.
- Compile and don't worry about the warnings.
- Go to the Windows Start Button and click on Run.
- Open: cmd.
- After > type `cd C:\ArduinoToAVRStudio-debounce\default.`
- After > type: `avrdude -p m328p -c avrisp -P com6 -b 57600 -F -U flash:w:Debounce.hex` remembering that your device may not be on com6.
- Press the reset button on the Arduino and the enter key on the PC.

The AVRStudio version of the Debounce code is also available in the Workshop10.zip. And, as a reminder, yes – this is harder than using the Arduino IDE, but it provides a clear path to C programming using the Atmel official tools, which is the direction I'll be going with future Workshops.

Push the button and the LED state toggles between on and off. That was fun, and now, as shown in **Figures 10 and 11**, you have what is

```

C:\WINDOWS\system32\cmd.exe
C:\ArduinoToAVRStudio-Blink\default>avrdude -p m328p -c avrisp -P com6 -b 57600 -F -U flash:w:Blink.hex

avrdude: AVR device initialized and ready to accept instructions

Reading : ##### : 100% 0.05s
avrdude: Device signature = 0x1e950f
avrdude: NOTE: FLASH memory has been specified, an erase cycle will be performed
        To disable this feature, specify the -D option.
avrdude: erasing chip
avrdude: reading input file "Blink.hex"
avrdude: input file Blink.hex auto detected as Intel Hex
avrdude: writing flash (2760 bytes):
Writing : ##### : 100% 1.38s
avrdude: 2760 bytes of flash written
avrdude: verifying flash memory against Blink.hex:
avrdude: load data flash data from input file Blink.hex:
avrdude: input file Blink.hex auto detected as Intel Hex
avrdude: input file Blink.hex contains 2760 bytes
avrdude: reading on-chip flash data:
Reading : ##### : 100% 1.20s
avrdude: verifying ...
avrdude: 2760 bytes of flash verified

avrdude: safenode: Fuses OK
avrdude done. Thank you.

C:\ArduinoToAVRStudio-Blink\default>
  
```

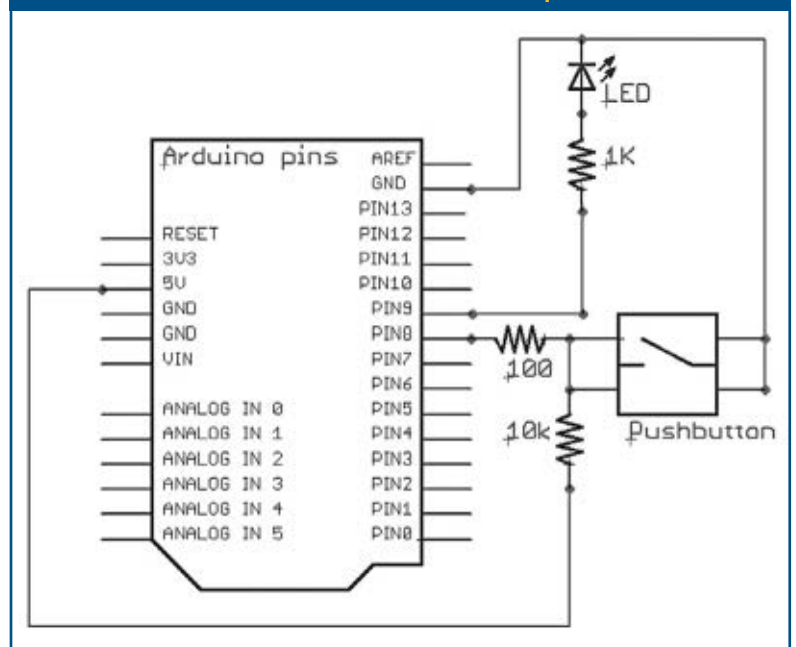
■ FIGURE 9. AVRdude upload.

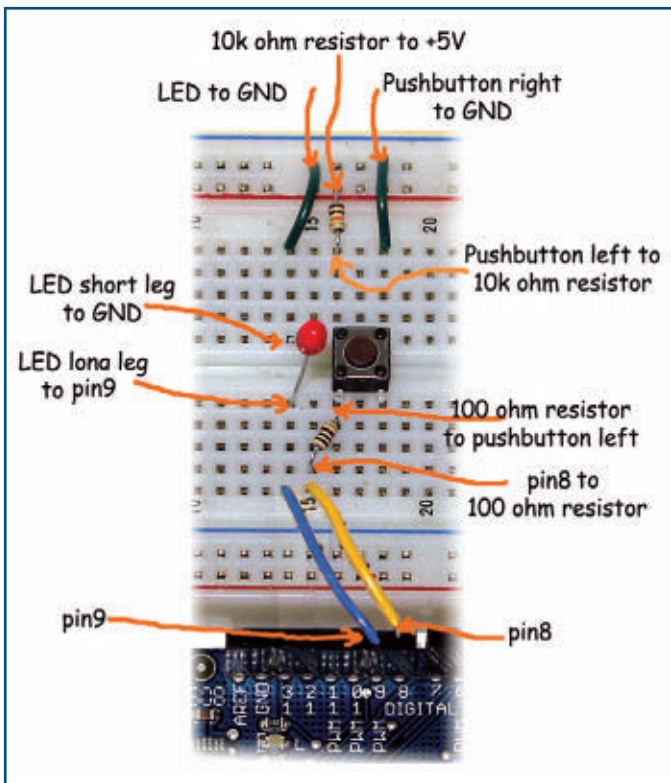
essentially a very expensive light switch, but who said learning was cheap?

Using PWM to Fade an LED

We can use the LED attached to pin 9 to demonstrate PWM (Pulse Width Modulation). **Figure 12** shows the ALPs being waved up and down with the LED fading in and out. Notice that the red streaks seem like beads whereas the green streaks are smooth. This is because the red LED is being turned on and off every ~33.3 times per second, with the on time varying. The camera lens was left open to capture several hundred of those intervals. Look at the center of the red streaks and you will see each red ‘bead’ gets progressively brighter until they seem to blend

■ FIGURE 10. Schematic for LED and pushbutton.





■ FIGURE 11. Close-up of LED and pushbutton breadboard layout.

in the brightest part of the sweep.

The concepts behind PWM are worthy of a full Workshop (or two), but as you will see from the source code, it is actually a fairly simple concept. There are two loops: one for fading in and the other for fading out. Each loop steps through 0 to 255 in increments of five and uses that value in the Arduino `analogWrite()` function that sets the length of time the LED is turned on in each cycle. When you look at the LED sans shaking, it seems to brighten and fade smoothly since the eye/brain smooths out rapidly blinking lights. This phenomenon is called persistence of vision (POV) and is the same thing that makes movies and TV seem to move smoothly when, in fact, you are seeing a sequence of still images.

For this exercise, we will assume that you learned enough in the first two examples to convert the Arduino Fading example code yourself (if not, you can find the converted example in `Workshop10.zip`). Please note that when I did this last example, I forgot to close the Arduino IDE — which had the com port open causing an AVRdude synch error — AND I forgot to add the `F_CPU` to the `wiring.c` file. You have to be patient and persistent doing this kind of work. So, don't feel too bad when you make the inevitable dumb mistakes like I make. It is part of the process, so learn to enjoy it. **NV**

You can find the source code and supplements for this article in `Workshop10.zip` on the *Nuts & Volts* and Smiley Micros websites.

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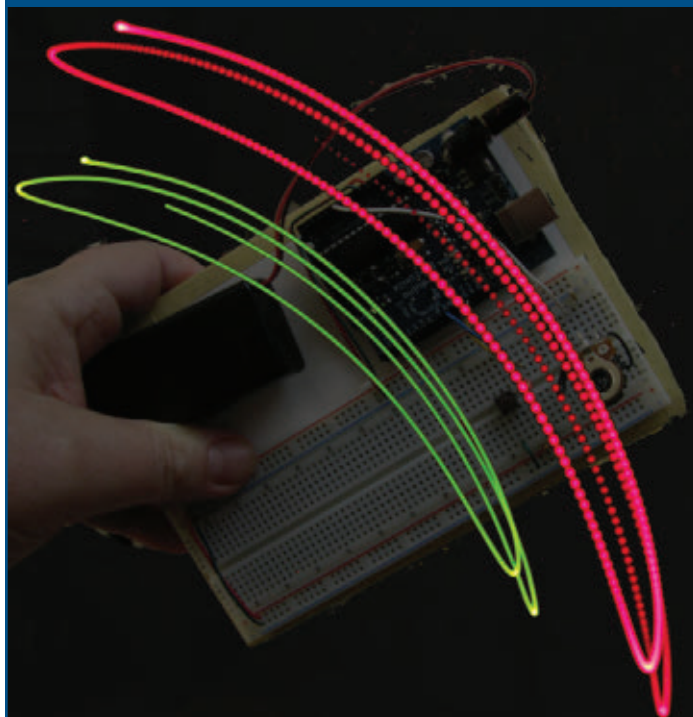
Smiley Micros and *Nuts & Volts* are selling a special kit — the Arduino Projects Kit providing components for use with Smiley's Workshops 9, 10, and many future Workshops. Over time, we will learn simple ways to use these components, and more importantly we will use them to drill down into the deeper concepts of C programming, AVR microcontroller architecture, and embedded systems principles.

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One final note: The USB serial port on the Arduino uses the FTDI FT232R chip. This was discussed in detail in the article "The Serial Port is Dead, Long Live the Serial Port" by yours truly in the June 2008 issue of *Nuts & Volts*. You can also get the *Virtual Serial Programming Cookbook* (also by yours truly) and associated projects kit from either *Nuts & Volts* or Smiley Micros.

■ FIGURE 12. PWM Fade.



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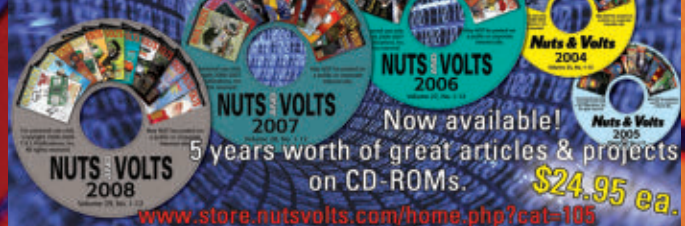
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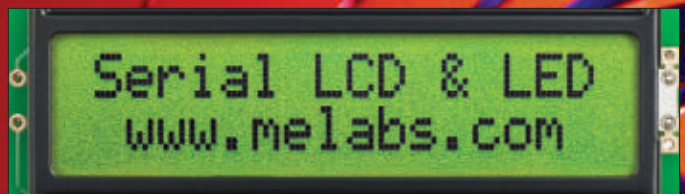
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STAMP APPLICATIONS

PUTTING THE SPOTLIGHT ON BASIC STAMP PROJECTS, HINTS & TIPS

■ BY JON WILLIAMS

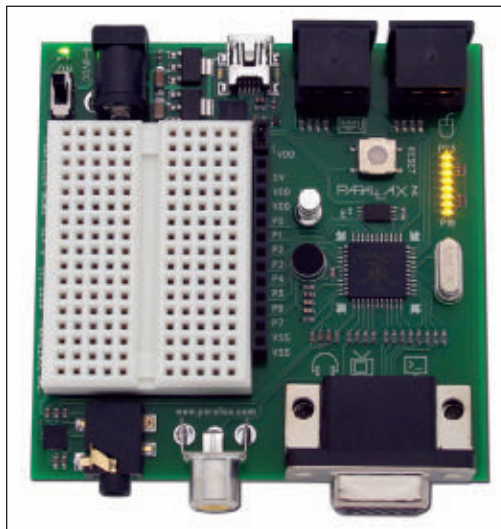
SPINNING UP EMBEDDED CONTROL PROJECTS

ONE OF MY DEAREST FRIENDS is a gentleman named Cliff Osmond. In addition to being my friend, he is my acting coach and as acting is about life, I learn a lot about life as I spend time with him. He's been around the block a few more times than me and what he has to say is valuable. Not long ago, he said that — as an actor — we have to be comfortable with being uncomfortable, because that's when we're really alive. It's an acting lesson and a life lesson, and time to apply it to my embedded control projects. I've become happily comfortable with the SX the last couple years and at the urging of several friends and readers, I'm going to delve more into the Propeller. Don't worry, from time to time I'll use the SX and BASIC Stamp, but getting out of my comfort zone — at least for a while — is going to be good for me. And fun!

(RE) INTRODUCING THE PROPELLER CHIP

The Propeller is the latest in Parallax's line of microcontrollers though it differs from the BASIC Stamp and Javelin in that it is completely custom silicon designed in-house entirely by Parallax staff. I often refer to the Propeller as a "multi-processor" instead of a microcontroller because it is comprised of eight 32-bit processors (which Parallax calls "cogs") that are controlled by a central "hub." Each cog has its own RAM so it can run independently, and it can communicate and share information with other cogs through shared RAM in the hub. The hub also handles gritty details like the system clock (which all cogs use and keeps them in sync) and provides access to shared resources like the system RAM and ROM tables.

As advanced as it is, the Propeller maintains some of the genetic material born out of the original BASIC Stamp. For starters, it is programmed through a simple serial port; no special tool is required. And like the Stamp, the Propeller's program is stored in an off-board EEPROM



■ FIGURE 1. Propeller Demo Board.

(32K). This last point has stuck in the craw of some professional developers as code stored in an off-board EEPROM is easy to read and clone. This issue is being addressed in the next-generation Propeller by encoding the EEPROM with an encryption key that is burned into the Propeller (OTP). This encoding will cause the contents of the EEPROM to look like gibberish to any Propeller chip that does not contain the proper key. Those with Stamp experience know that running code from an external EEPROM can take a real toll on overall speed. The Propeller borrows from another Parallax product — the Javelin Stamp — in

that the EEPROM image is moved into the system (hub) RAM on power-up. Using internal RAM gives us a tremendous speed boost and frees the EEPROM pins (28 and 29) for other tasks. I tend to use these pins as a general I²C bus as they're predefined that way for loading the Propeller code.

If you're brand new to the Propeller, please see my articles in the April, May, and June 2006 issues of *Nuts & Volts*; back issues are available online at www.nutsvolts.com.

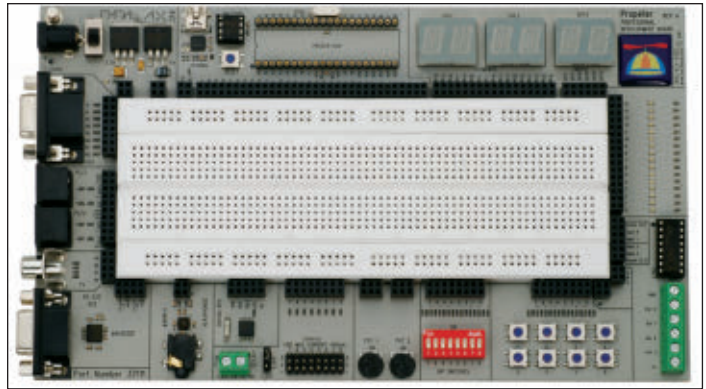
DEVELOPMENT TOOLS

Getting started with the Propeller means we'll need some sort of development platform and having been around a few years now, there are a number of offerings from Parallax and several third parties – including anything we design ourselves. I have a few of the Parallax boards that I use when developing my own projects but that's not to say that products offered by others aren't equally excellent; I just don't have experience with them.

Many will start with the Propeller Demo Board shown in **Figure 1**. This is a nice little board for doing demos (hence the name) and small experiments but may hold you back when you start getting into bigger projects. If this is what you have, great – it has all the connectors you need for the fun stuff like audio, video, mouse, and keyboard, and has several LEDs which let you do lots of code training without ever having to wire anything.

On the other end of the scale – and my favorite piece of Propeller gear – is the Propeller Professional Development Board (PPDB) shown in **Figure 2**. This is descended from the tremendously successful Professional Development Board (PDB) that many pros use to develop BASIC Stamp and SX projects. I know that some of you will cringe at the PPDB price tag (about \$170), but I hope you'll believe me when I tell you it is worth every cent and so much more. As I just stated, I do a lot of development work for EFX-TEK using the PDB and the PPDB is the answer to my wishes for a similarly equipped board for the Propeller. When I'm developing projects, I don't want to go looking for anything except some hook-up wire (I keep a lot of it on my bench); with the PDB and PPDB, I can focus on code and connections instead of looking for resistors and LEDs.

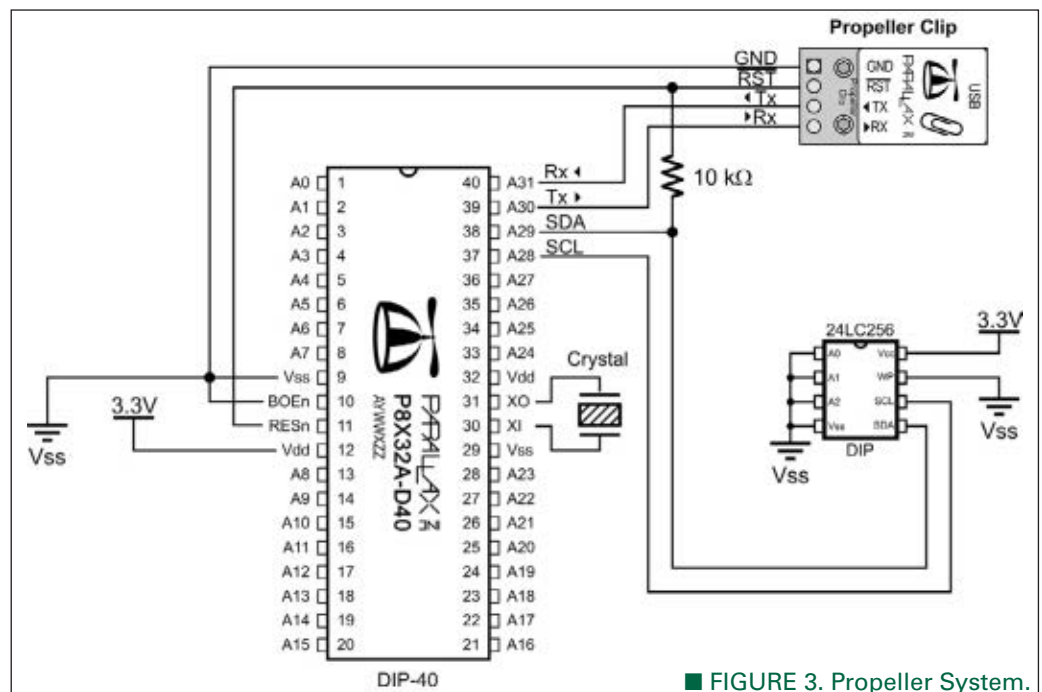
What if you already have a PDB? You could (as I did prior to the PPDB) add a 3.3V regulator to the PDB breadboard and build a standard Propeller demo circuit (**Figure 3**) on the breadboard. If you're not familiar with the Propeller but are familiar with I²C, you may wonder why Parallax schematics have only one pull-up on the bus – just on the SDA pin. For reasons unknown to me, the Propeller drives the I²C SCL line high and low when transferring the EEPROM contents to hub RAM. After the hub is loaded, both pins float and you can use other I²C devices on these pins – just make sure you don't write to EEPROM (I²C device type %1010) address %000



■ FIGURE 2. Propeller PDB.

as you could corrupt your program. If you're going to use pins 28 and 29 for other I²C devices in your project, be sure to add a pull-up to pin 28. IMPORTANT NOTE: If you decide to connect additional EEPROMs (device type %1010) to pins 28 and 29, you must ensure that they are addressed %001 and higher. The PPDB is a great tool, but at some point we'll want to make a project permanent. For my semi-permanent and permanent projects, I decided to "liberate" a good idea from another microcontroller platform: the Arduino. The original Arduino has a base platform with the microcontroller, power, programming, and I/O connections, and what many have done is created various application "shields" that plug into the base board.

In **Figure 4**, you can see the first version of what I call my Propeller Platform. There is nothing magic at all about this board (see the schematic in **Figure 5**); I used the ExpressPCB mini-board size and built a standard Propeller circuit on it – with an additional socket for another EEPROM (address %001). The board goes together in just a few minutes using all through-hole parts.



■ FIGURE 3. Propeller System.



After building the board, I made some refinements to the design files that you can download from *Nuts & Volts*: I changed the power switch to a right-angle style and found shorter caps for the power supply that allow a daughterboard to fully seat in the power and I/O sockets. The idea behind the Propeller Platform is to have a known good processor base that can move from project to project as desired — this should help keep the costs of future projects a little more manageable. One final note on the board: To keep the crystal low on the PCB, I used two elements from a machine pin socket. You have to be careful removing the plastic but doing that will allow it to seat cleanly in the PCB.

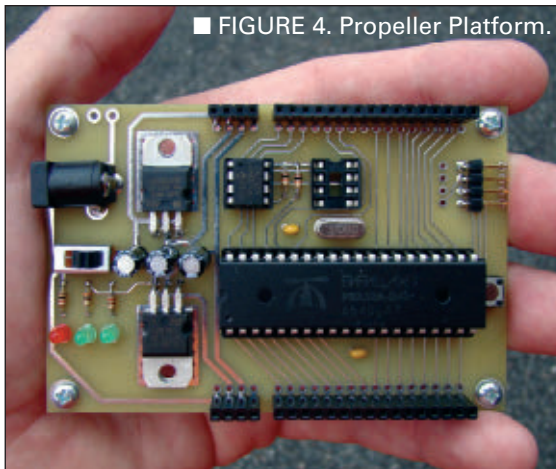
PROGRAMMING THE PROPELLER

The BASIC Stamp started a revolution in small, high-level microcontrollers bringing the Basic language that many of us learned as youngsters to the world of embedded control. One would think, then, that being a Parallax product, the Propeller would be programmed in Basic, as well. After all, how many PBASIC knockoffs exist today? Too many to count — a tribute to how well PBASIC performed and was accepted. In the end, though, when Parallax designed the Propeller they looked at other programming languages, especially those designed for coding efficiency, and from that study created a slightly unique yet familiar feeling high-level language called “Spin.”

Like PBASIC, Spin is an interpreted language but the difference stops right there. As mentioned earlier, Spin byte codes are run from the system RAM instead of an EEPROM so there is a huge speed increase; the processor running Spin tends to run at 80 MHz (more on that in a moment), and the Propeller is built on a 32-bit architecture which means it can do a lot of work with very few instructions. An interesting difference between the Propeller and the other HLL (high-level language) modules on the market is that Spin was developed in tandem with and specifically for “brains” underneath. Most other embedded HLLs are created on top of existing microcontroller products and may, in fact, not always be as efficient as one would like.

As Spin and the Propeller Assembly language were created at the same time, there are very close ties between them which allows Spin — even though it’s a high-level language — to be very efficient. And it’s easy to use. I like Spin because it caters to my whacky desire for neat program listings; Spin actually uses indentation to define structures within the code. For those used to “messy” programming, you may have to get used to this, while some coming from high-level scripting languages like Python will feel right at home.

■ FIGURE 4. Propeller Platform.



CONNECTING SPIN AND ASSEMBLY

An interesting thing about the Propeller is that after reset, it defaults to Spin. Even if we want to write the entire application in Assembly, we have to use a very simple Spin program to launch it so the connection between Spin and Assembly is important. If I was going to allow myself to fall into old habits, I’d stick with nothing but Spin for a while, but hey, let’s push past our comfort

level and learn some new tricks, shall we?

In March, I had the opportunity to participate in a webinar with my friend and old Parallax colleague, Jeff Martin. Of particular interest to me was the connection between Spin and Assembly — put in terms that I could understand and use in my own projects. While I don’t normally believe in simple demo code, I’m presenting an updated version of a program Jeff created for me. You can use this to test your own Propeller Platform. This doesn’t do a heck of a lot, but clearly illustrates the connection between Spin and Assembly and cooperative work between cogs.

Let’s cover the Spin section first.

```
CON
    _clkmode = xtal1 + pll16x
    _xinfreq = 5_000_000

VAR
    long    cmd
    long    paramL1

OBJ
    terminal      : "simple_serial"
    myVal         : "numbers"

PUB Main
    cmd := 0
    cognew(@ASM, @cmd)

    terminal.Init(31, 30, 19200)
    myVal.Init

    terminal.tx(12)
    terminal.str(myVal.tostr(incval(100),
myVal#DDEC))
    terminal.tx(13)
    terminal.str(myVal.tostr(decval(1000),
myVal#DDEC))

    repeat

PUB incval(val) : result
    paramL1 := val
    cmd := 1
    repeat while cmd <> 0
    result := paramL1

PUB decval(val)
    paramL1 := val
    cmd := 2
    repeat while cmd <> 0
    result := paramL1
```

The CON section is what we'll tend to use as a standard: 5 MHz crystal with the PLL cranked up to 16X so we're running the cogs at 80 MHz.

In the VAR declarations, we define two longs that will be used to communicate with the Assembly cog. The purpose of our demo is to send a command and value to the Assembly cog; the command will tell the Assembly cog what to do with the value.

In the OBJ section, we reference a serial object to send information to a standard terminal (I tend to use HyperTerminal) and an object called *myVal* which allows us to create formatted numeric strings for the terminal.

At the top of Main, we start by clearing *cmd* and then launching the Assembly cog with the **cognew** function. Since we're going to launch Assembly code, we need to provide a pointer to it using the @ symbol with the name of the label used (ASM). The next item in the function is the address of the command variable. As all cogs have access to the system RAM, this allows the Spin and Assembly sections to work together. The address of *cmd* will be passed to the Assembly section inside the Propeller using the *par* register.

Okay, let's have a look at the Assembly section.

DAT

```
org 0
```

```

ASM      mov     cmdAddr, par
         mov     valAddr, par
         add     valAddr, #4

WaitForCmd  rdlong tmpL1, cmdAddr
         tjbz    tmpL1, #WaitForCmd

CheckCmd   cmp     tmpL1, #1      wz
         if_z    jmp     #Increment
         cmp     tmpL1, #2      wz
         if_z    jmp     #Decrement

BadCmd     wrlong  zero, cmdAddr
         jmp     #WaitForCmd

Increment  rdlong  tmpL1, valAddr
         add     tmpL1, #1
         wrLong  tmpL1, valAddr
         wrLong  zero, cmdAddr
         jmp     #WaitForCmd

Decrement  rdlong  tmpL1, valAddr
         sub     tmpL1, #1
         wrLong  tmpL1, valAddr
         wrLong  zero, cmdAddr
         jmp     #WaitForCmd

` ENDASM

cmdAddr   long    0
valAddr   long    0

tmpL1     long    0
zero      long    0
    
```

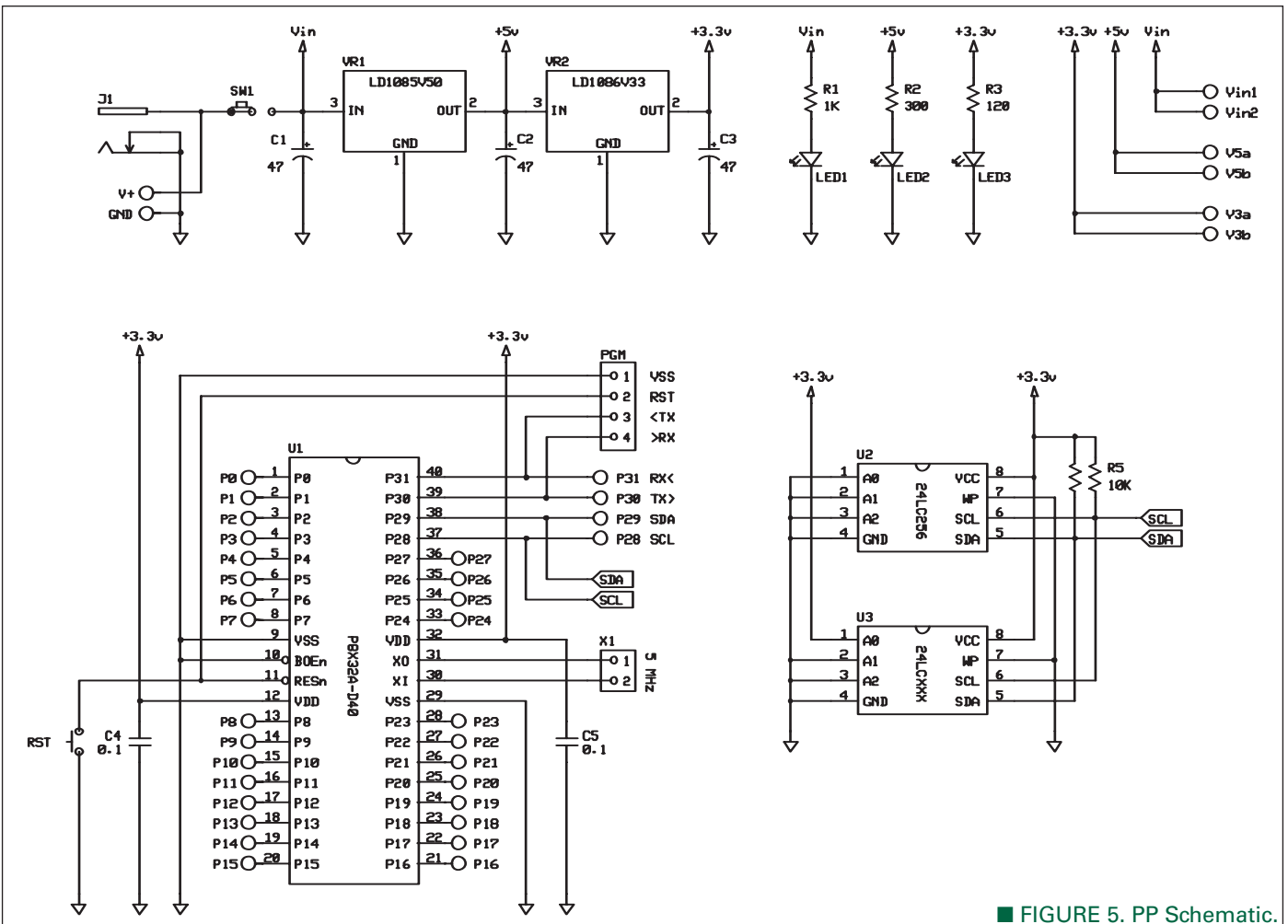


FIGURE 5. PP Schematic.

If you look at the contents of any programmed microcontroller, it would look like a bunch of random values that could be program code or data; it's the location of these values that allows the microcontroller to interpret them as what they actually are. This means, then, that we will write our Propeller Assembly code inside a DAT block of a Spin program. When we launch the new cog, this code is copied from the Spin DAT section into the new cog's RAM to run.

The first thing our program does is retrieve the *par* register which is holding the address of the command that we're going to use later. This is copied to a local (inside the new cog) variable called *cmdAddr*. In actuality, we need to know two addresses: the address of the command value and the address of the variable to work on. As we can only pass one long to the Assembly section, we placed our variables in order in the Spin section; in the Assembly section, we can determine the address of the variable to work on by adding four (four bytes per long and hub memory is always addressed as bytes) to the value in the *par* register; this will be stored in *valAddr*. Using this strategy, an Assembly program can operate on as many system variables as may be required.

Here's what the Assembly program is going to do: It will wait for a command from Spin, interpret the command, and then do something with the variable located in *valAddr*. The Assembly section knows it has a command when the value in *cmdAddr* is non-zero. A two-line loop at the top will cause this Assembly program to wait using the **tjz** (test, jump on zero) instruction.

Once a command is detected, it is tested for one or two: one for increment, two for decrement. Note that Propeller Assembly allows the programmer to determine the effect an instruction has on flags. We're telling the **cmp** (compare) instruction to set the wz bit when the

result is zero (this signifies a match). After the compare, we test the zero flag (**if_z**) and jump to the appropriate routine. The Increment section retrieves the value from *valAddr*, adds one to it, then puts the new value back. The code at Decrement is identical, save for the fact that it subtracts one.

Now the important part: The command value in *cmdAddr* is cleared to zero. Let's go see why.

Back in the Spin code, you'll see a function called **incval** that is going to be used to increment a value passed to it. The value passed is moved to *paramL1* which the Assembly section tracks in *valAddr*. Then we set *cmd* (which the Assembly tracks in *cmdAddr*) to one to indicate an increment. An important reminder here is that the **cognew** function started the Assembly code in its own processor (cog) and it is running concurrent with and yet independent of the cog running the Spin program. It is the sharing of the locations of *cmd* and *paramL1* that lets them work together.

Since both programs are running at the same time, we have to store the value first and then change the command. As soon as the command is changed to a non-zero value, the Assembly program is going to take action. Remember how we had the Assembly section clear a command to zero when finished? We can see now how this is used by the Spin program: After setting the command value, a simple **repeat** loop holds the program until the command is cleared before returning the updated value to the caller.

When you run the program, your terminal will print two numbers: 101 and 909. These values are returned from the **incval** and **decval** functions in the Spin program, but the actual incrementing and decrementing took place in the Assembly program.

Okay, I know this program is barely a step up from blinking LEDs but I think it's really important to get a good grasp on the mechanics of connecting Spin and Assembly if we're going to take advantage of all the horsepower the Propeller has to offer. Do take a few minutes to load this program into your development system — whatever it might be — and run it. Better yet, run it and then modify it to do something more. Go beyond your comfort zone; this will make you a better programmer.

INTERVALOMETER FOLLOW-UP

Just a quick note for those that have or are considering building the intervalometer project from the March column: A friend of mine pointed out that one of my favorite places in Los Angeles (All Electronics) has a stick-on IR LED cable that is normally used for controlling VCRs; this makes the IR connection to the camera much more reliable. Look for part #IR-21.

Another option — and the one I prefer — is an IR Extender from www.smarthome.com; the part number is #8170S. This costs more than the

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▶ R1	1K	Mouser 299-1K-RC
▶ R2	300 Ω	Mouser 299-300-RC
▶ R3	120 Ω	Mouser 299-120-RC
▶ R4-R5	10K	Mouser 299-10K-RC
▶ RST	N.O. pushbutton	Mouser 653-B3F-1002
▶ SW1	SPDT	Mouser 506-SLS121RA04
▶ U1	P8X32A-D40	Parallax P8X32A-D40
▶ U2	24LC256	Mouser 579-24LC256-I/P
▶ VR1	LD1085V50	Mouser 511-LD1085V50
▶ VR2	LD1086V33	Mouser 511-LD1086V33
▶ X1	5 MHz	Parallax 251-05000
▶ S1	40-pin	Mouser 571-1-390262-5
▶ S2-S3	Eight-pin	Mouser 571-1-390261-2
▶ SV1-SV2	Board mount conn	Mouser 517-974-01-04-RK
▶ SPx1-SPx2	Board mount conn	Mouser 517-974-01-16
▶ SXR	Machine pin socket	Mouser 506-510-AG90DD1

unit from All Electronics but is manufactured by them so you never have to worry about supplies. It's also quite a bit smaller so I find it easier to mount to my camera. Either way, using one of these stick-on emitters ensures we won't be missing any important shots with the intervalometer.

That's about it for now — until next time, Happy Spinning! **NV**

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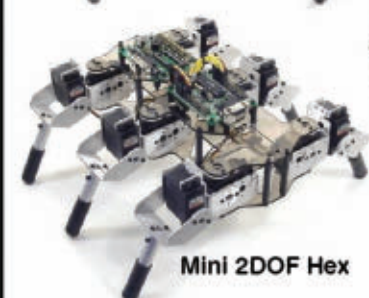
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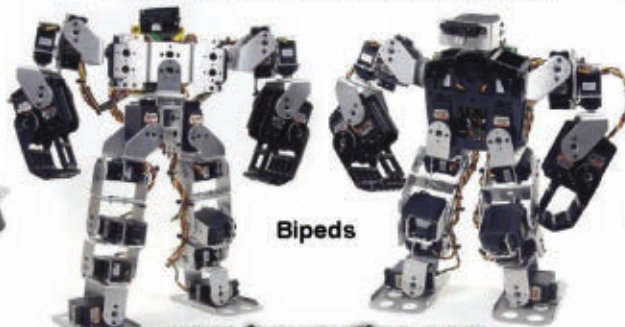
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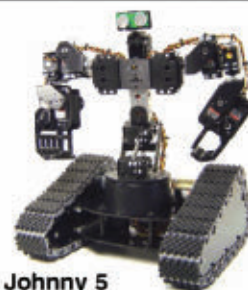
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■ BY FRED EADY

AND NOW, A RIFF FROM JEFF BECK

DURING MY STINT IN JUNIOR HIGH AND HIGH SCHOOL, I picked up almost every brass instrument in the band (except the tuba, trombone and Sousaphone) and performed with them. I couldn't get enough music. So, I started hanging around the local music store and before I knew it, I was thumping my bass guitar along with the high school's jazz band, choir and pep band. Life was really good as during this time I was also working nights as a Rock/R&B disk jockey at the local AM radio station, WEKR. As far as I was concerned, my life's work was set in stone. I was to be a musician or better yet, a recording engineer. After all, I had scratch built a couple of guitar amplifiers by this time in my life and electronics was indeed my second love.

Obviously, Cyndi Lauper isn't ringing my phone to book a session and Mick Jagger doesn't hang around the house as much as he did in those days. However, I still play guitar and blast my stereo way too loud. I've wanted to do an audio Design Cycle piece for a long time but I just couldn't come up with a combination that would cover a musical subject and provide a useful project for the non-musician, as well.

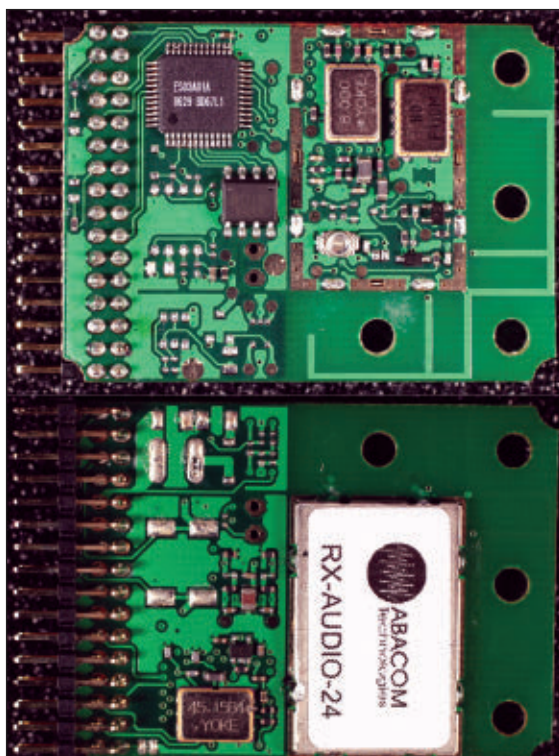
In recent days, I've found myself falling in love with my guitar (and all of the goodies that go with it) once again. I use a Shure professional wireless setup to connect to my classic Fender Princeton Reverb valve (that's British for tube) amplifier. Being wireless allows me to freely jump around the living room and be silly while playing along with Queen, Led Zeppelin, and Pink Floyd.

I had just finished up a "How To" article that described the steps and equipment necessary to implement an embedded data radio link. So, while strumming

along to "Wish You Were Here," I thought to myself, why not do an RF piece that not only transmits data, but also transmits high quality audio?

DESIGNING A WIRELESS GUITAR SYSTEM RECEIVER

I'm a firm believer that RF engineers are members of the *dark side*. Think about it. These guys and gals design electronic equipment festooned with simple coils of wire that emit magical data-laden waves that travel invisibly through the ether of Earth. Then, they design and build these *black boxes* that can capture the magic waves and turn them into sound or parlay them into data. They support this demonic behavior by pointing out that we embedded electronic types also use invisible dark agents we call electrons to do our dirty work. Well, at least our electrons can be physically located and identified as they must travel from Point A to Point B within a three-dimensional, electrically conductive substance such as a wire or a printed circuit



■ **PHOTO 1.** This version of the RX-AUDIO-24 receiver module doesn't have the headphone amplifier components mounted. That's fine as the output of our receiver will be feeding the low level input of a guitar amplifier.

■ **SCHEMATIC 1.** Every part in this schematic is available off the shelf from Digi-Key and Mouser. You can order the RX-AUDIO-24 receiver module directly from ABACOM via their online store.

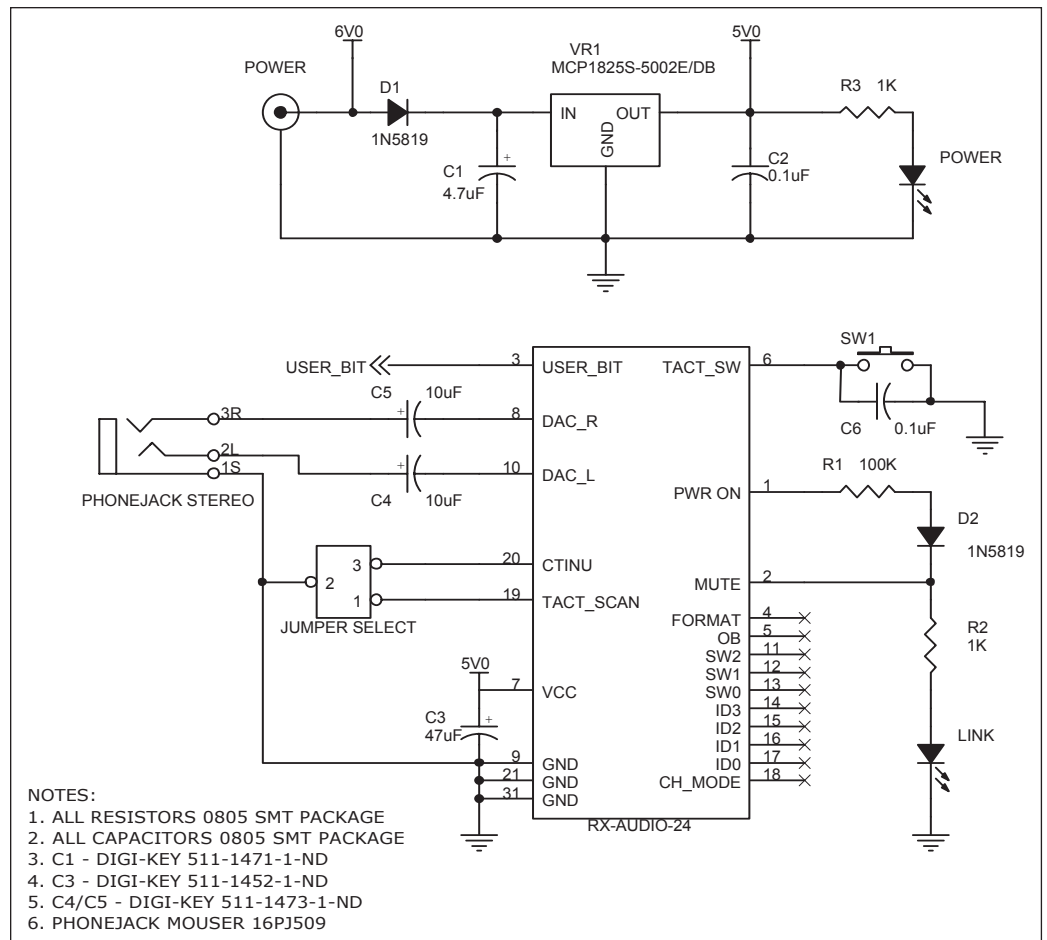
board trace. Dark side or not, I've got to admit that the technology of RF communications is a necessary evil as it frees us from the restrictions of pushing electrons around over a discrete length of wire. This rings especially true for today's musicians as they can now roam all over the stage and into the crowd with their microphones and instruments in tow.

Our wireless guitar system will need a high quality receiver that has a fair amount of sensitivity. We'll also need to be able to defeat interference from competing electronic devices. Fortunately, we won't have to don a pointy hat with moons and stars all over it to bring such a receiver to life. Our wireless guitar system is designed around the ABACOM RX-AUDIO-24 receiver module.

The RX-AUDIO-24 is a multi-channel, high quality, digital stereo receiver module with a reception range of up to 100 feet LOS (line of sight). Measuring in at 1.26 inches x 1.74 inches, the module and its embedded antenna are small enough to be fitted into an enclosure that clips onto your belt.

Power consumption of the RX-AUDIO-24 is typically 65 mA at 5.0 volts. Operating in the 2.4 GHz ISM (Industrial, Scientific, and Medical) band, the RX-AUDIO-24 is capable of receiving FSK (Frequency Shift Keying) modulated digital signals on one of eight channels, which are spaced at 9 MHz intervals. Originally designed for use in portable high fidelity applications, the RX-AUDIO-24 has an audio frequency response range of 20 Hz to 20 kHz with a THD (Total Harmonic Distortion) figure of 0.1%. The receiver section sensitivity is rated at -85 dBm with a S/N (Signal-to-Noise) ratio of 87 dB. The maximum output level of the RX-AUDIO-24 is 3.4 volts peak to peak, which is more than enough to drive the preamp of a Fender guitar amplifier. For the dB and dBm challenged of you out there, all I really just said is that the RX-AUDIO-24's receiver circuitry is sensitive and its audio circuitry is quiet.

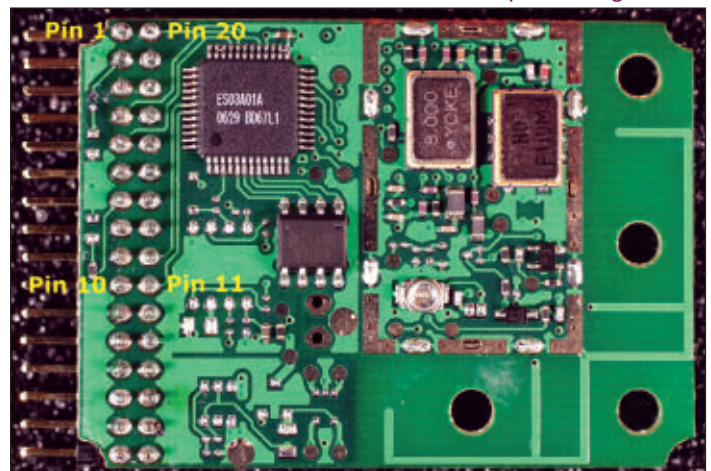
The RX-AUDIO-24 module we will use in our wireless guitar system can be seen front and back in **Photo 1**. All of the RX-AUDIO-24 module's functionality is accessible

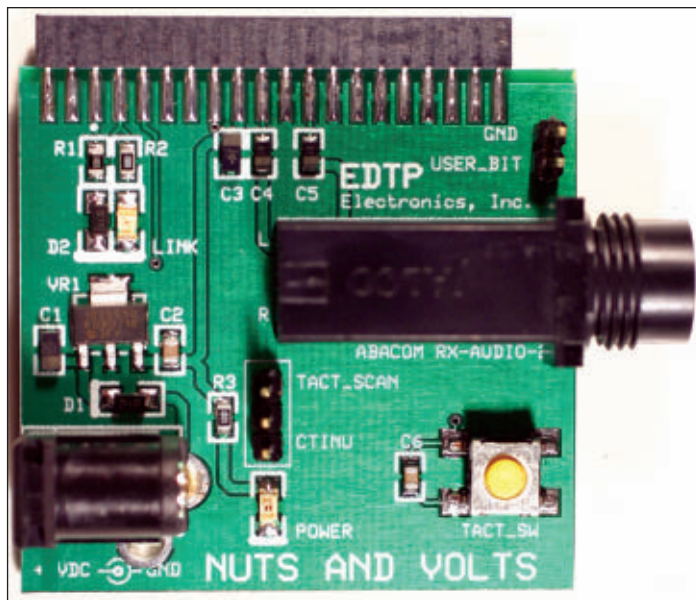


via its 32-pin 2 mm header. If you're wondering why there are so many unpopulated component pads, our version of the RX-AUDIO-24 does not have the headphone amplifier circuitry installed. As the output of the module will be feeding the low-level input of a guitar amplifier, the absence of the headphone amplifier components matters not to us.

In that the headphone amplifier section of the

■ **PHOTO 2.** As you can see, the pin layout is not at all intuitive to the most casual observer. That's fine. We can easily design our receiver support printed circuit board around this pin arrangement.





■ **PHOTO 3.** Piece of cake. The minimal component count and uncluttered layout of the receiver support electronics make for quick and easy assembly.

RX-AUDIO-24 is disabled, we need only access 20 of the 32 pins in our wireless guitar system application. Now would be a good time to examine the function of each of those 20 pins using **Photo 2** and **Schematic 1** as guides.

Pin 1 – the PWR ON pin – rises from zero to +2.7 volts a couple of seconds after power is applied to the module. The intended use of this pin is to delay the turn on of an external power amplifier and thus eliminate the “pop” noise picked up by the external amplifier when the RX-AUDIO-24 is powered up. Note that the MUTE pin is used as a link indicator signal in our wireless guitar system application. Pin 2 emits a logically low voltage level when the RF signal is weak or nonexistent.

The RX-AUDIO-24 has the ability to chew gum and walk at the same time. In addition to the audio channels, it can also receive a digital data stream simultaneously. The audio and digital data do not interfere with each other. Digital data from the transmitter is demodulated and presented at the RX-AUDIO-24’s USER_BIT output. The USER_BIT function doesn’t care about the format of the digital data. The user need only keep the bandwidth of the data below 5,000 bps.

Let’s skip pins 4 and 5 for now and examine the functionality of pin 6. As you can see in Schematic 1, a simple pushbutton switch is attached

between the TACT_SW pin – which is pulled high internally – and ground. When the pushbutton is depressed, a logically low voltage level is applied to the TACT_SW pin, which triggers a channel change or channel scan operation. Grounding the TACT_SCAN pin enables a channel change with each pushbutton depression, while grounding the CTINU pin kicks off a channel scan. The TACT_SCAN and CTINU pins are also pulled high internally, and leaving them to float puts the RX-AUDIO-24’s receiver circuitry into AUTO SCAN mode.

Although we are only utilizing the RX-AUDIO-24 in a monophonic guitar application, it is stereo-capable. A standard monophonic guitar cable will feed the LEFT channel in our transmitter design. The resultant audio we glean from the RX-AUDIO-24 will be tapped from its DAC_L pin. For those of you that may be guitar challenged, the Rickenbacker Model 4003 bass guitar has a stereo output. All we have to do to support a stereo-enabled Ricky with our wireless guitar system is plug in at the transmitter using a stereo guitar cable and pick up the additional audio channel at the receiver’s DAC_R pin.

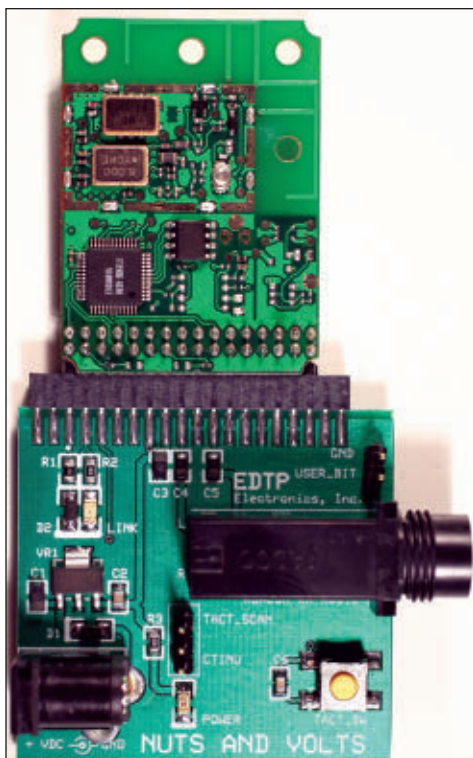
The RX-AUDIO-24’s pins 4 and 5 are internally pulled high and are not used in our wireless guitar system design. ID selection and DIP mode channel selection are also not implemented in this version of the RX-AUDIO-24. So, we will also leave the SWx and IDx pins to float on their internal pullups. Since there is no DIP mode channel selection, the RX-AUDIO-24’s CH_MODE pin is useless to us, as well. Pulling the CH_MODE pin logically low enables DIP mode channel selection, which doesn’t exist for us. So, we will also allow the CH_MODE pin to ride on its internal pullup resistor.

The RX-AUDIO-24 and its supporting circuitry can be powered from any six volt source such as a quad of series-connected AA or AAA 1.5 volt batteries. If you’re sure of your power supply polarity, mounting the blocking diode (D1) becomes optional. With that, let’s translate the graphics in Schematic 1 into components that mount on a piece of copper clad fiberglass.

ASSEMBLING THE WIRELESS GUITAR SYSTEM RECEIVER

This won’t take long as there are only 20 components to mount and solder. To make the assembly even easier, I’ve provided the ExpressPCB printed circuit board (PCB) file for you in the download package on the

■ **PHOTO 4.** Note the presence of a silkscreen dot denoting pin 1 of the RX-AUDIO-24 header just above resistor R1. Once you mate the RX-AUDIO-24 with the support printed circuit board, the receiver portion of our wireless guitar system is ready to rock.



■ **PHOTO 5.** Like the RX-AUDIO-24, the TX-AUDIO-24 carries an integral antenna along with the radio electronics in a compact 1.8 x 0.55 inch package.

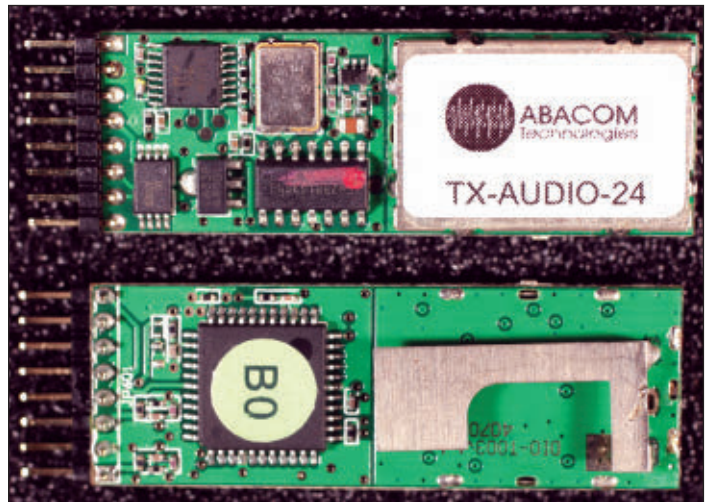
Nuts & Volts website (www.nutsvolts.com). My assembled wireless guitar system receiver support board is pictured in **Photo 3**.

I've listed the part numbers for the 0805 SMT tantalum capacitors in the NOTES area of Schematic 1. The RX-AUDIO-24 interfaces with the wireless guitar system receiver support PCB by way of a 40-pin 2 mm connector. The 2 mm connector can be had from Mouser as part number 855-M22-7142042. You'll find that the 2 mm connector fits perfectly on the edge of the PCB. Be sure to solder all of the 2 mm connector pins on both sides of the PCB. Schematic 1, Photo 3, and the Express PCB layout file provide you with more than enough component identification and placement information to assist in a trouble-free hardware build process. Once you've checked your work, you can attach the RX-AUDIO-24 module to the support PCB as shown in **Photo 4**.

THE TX AUDIO 24 TRANSMITTER MODULE

Schematic 2 pretty much says it all. The TX-AUDIO-24 is a stereophonic digital transmitter that only requires the support of a power source and four external components for proper operation.

As you can see in **Photo 5**, the TX-AUDIO-24 interfaces to its support electronics via an eight-pin 2 mm

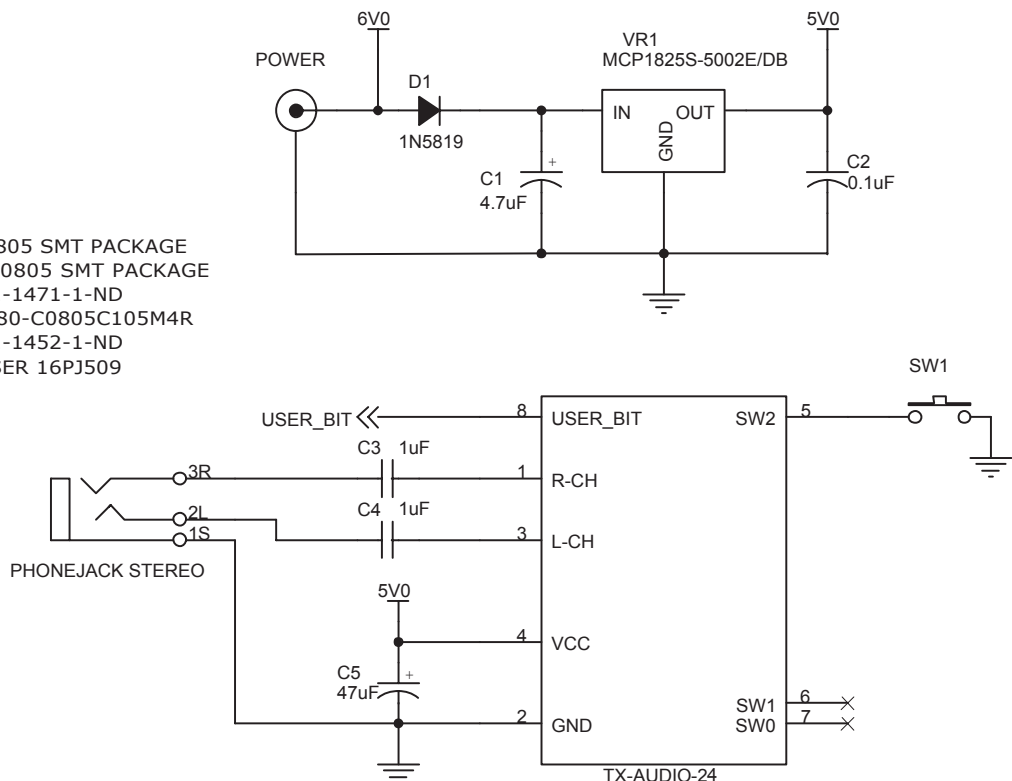


header. If the USER_BIT input is not utilized, the TX-AUDIO-24 only requires five of the eight header pins to be connected to external support circuitry. Basically, all the TX-AUDIO-24 needs from us is a power source and an audio source.

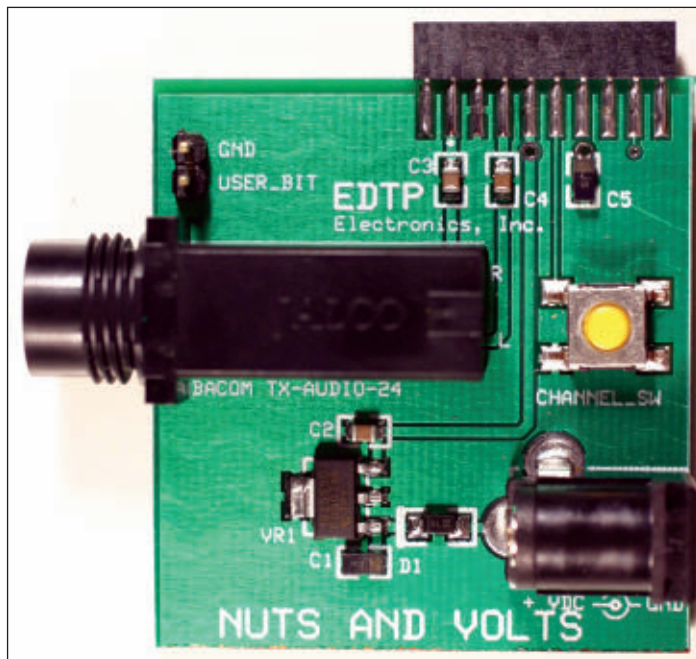
The TX-AUDIO-24 requires a power supply voltage between +3.6 and +5.0 volts DC. The current consumption is just a bit higher than the RX-AUDIO-24 coming in at 92 mA when the wind isn't blowing. As one would expect, the TX-AUDIO-24 transmits in the 2.4 GHz ISM band using one of eight channels that are spaced 9 MHz apart. A maximum input level of four volts peak to peak can be applied at the TX-AUDIO-24's audio inputs, which is well above the raw pickup output of most guitars.

NOTES:

1. ALL RESISTORS 0805 SMT PACKAGE
2. ALL CAPACITORS 0805 SMT PACKAGE
3. C1 - DIGI-KEY 511-1471-1-ND
4. C3/C4 - MOUSER 80-C0805C105M4R
5. C5 - DIGI-KEY 511-1452-1-ND
6. PHONEJACK MOUSER 16PJ509



■ **SCHEMATIC 2.** SW1 is used to switch to one of eight available channels.



High fidelity reception requires high fidelity transmission. The TX-AUDIO-24's audio frequency response, dynamic range, separation, signal-to-noise, and THD numbers match those of the RX-AUDIO-24.

ASSEMBLING THE WIRELESS GUITAR SYSTEM TRANSMITTER

When you download the wireless guitar system ExpressPCB layout file, you'll see that I have mounted the receiver layout on the same PCB as the transmitter. I've done this to reduce the cost of obtaining the boards from ExpressPCB. Instead of having to place two separate PCB orders, you now only need to order one board and separate its receiver and transmitter sections.

Every one of the 11 transmitter support components are looking at you in **Photo 6**. The power supply used by the TX-AUDIO-24 is identical to that of the RX-AUDIO-24. A couple of high quality 1.0 μ F ceramic capacitors isolate the TX-AUDIO-24's LEFT and RIGHT inputs. I don't think you'll have any problem assembling this. So, when you're done you can mate the TX-AUDIO-24 module to its support PCB as I have done in **Photo 7**. By the way, the 20-pin 2 mm socket is

■ **PHOTO 6.** There isn't much to talk about here as most of the transmitter complexity and circuitry can be found on the TX-AUDIO-24 module proper. This would be a good time to give you the Digi-Key part numbers for the power connector (CP202A-ND) and the pushbutton (SW416-ND).

available from Mouser as part number 855-M22-7141042.

USING YOUR NEW WIRELESS GUITAR SYSTEM

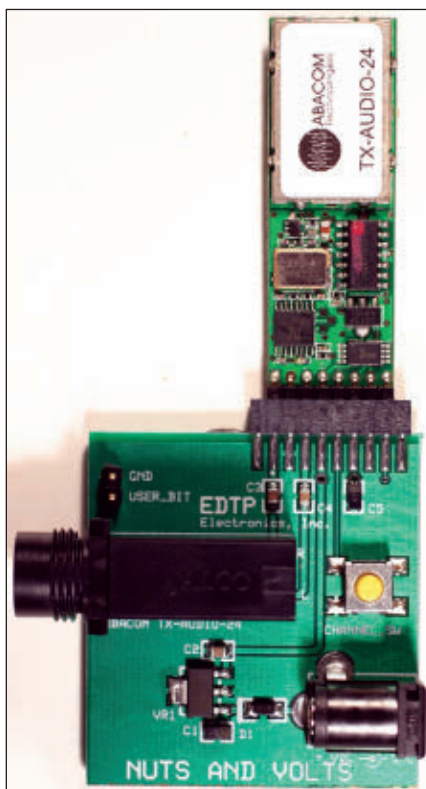
All you really have to do at this point is apply power to the transmitter and receiver modules. If you leave the RX-AUDIO-24 jumper select pins open, you should see the RX-AUDIO-24 module's LINK LED illuminate once the automatic channel scan completes. Jumper the TACT_SCAN pin to ground and play with the channel select buttons on the transmitter and receiver while observing the LINK LED. Do the same with the CTINU pin grounded. You'll be able to see the difference in manually scanning for a channel button press by button press and continually scanning for a channel with a single pushbutton depression.

I tested the audio capability of the wireless guitar system using a Fender Stratocaster and a Fender Princeton Reverb amplifier. I powered the TX-AUDIO-24 and RX-AUDIO-24 with identical six-volt battery packs made up of four AA batteries. The ABACOM radio link worked as designed and as advertised.

TINKER TIME

I've presented just one possible application for the ABACOM RX-AUDIO-24 and TX-AUDIO-24 modules. These units can be used in most any high-quality wireless audio application. In addition, you can exploit the simultaneous audio/data transfer capability of the modules by adding a microcontroller to the mix. The USER_BIT pin can be driven with any microcontroller communications protocol including RS-232, I²C, and SPI. You may also invent and send your own protocol over the USER_BIT digital data link.

Although the RX-AUDIO-24 and TX-AUDIO-24 modules we discussed did not contain amplifier or ID selection circuitry, you are now able to obtain versions of the modules that do indeed include a headphone amplifier and active ID selection circuitry. The TX-AUDIO-24/AE variant also differs from the TX-AUDIO-24 in its reduced power supply voltage (3.3 volts DC), power consumption (68 mA), and external quarter wave



■ **PHOTO 7.** Again, please note that pin 1 of the TX-AUDIO-24 is identified with a silkscreen dot. This time, the pin 1 designator is directly above capacitor C3.

wire whip antenna. The audio input voltage level of the TX-AUDIO-24/AE differs as well, and is reduced to two volts peak to peak.

Things audio are always unique to the listener. So, feel free to experiment with the input and output capacitor values. For instance, the ABACOM application notes and datasheets say that you can realize an increase in low frequency response by increasing the values of the input and output capacitors set forth in the basic design rules.

I've got the urge to pull out my Rickenbacker 4003 bass guitar, hook up my new wireless guitar system in stereo, and join Rick James in a living room rendition of *Super Freak*. Meanwhile, while I'm rocking out with Rick, you can add wireless stereophonic audio transmission to your Design Cycle. **NV**

SOURCES

ABACOM Technologies, Inc. — www.abacomdirect.com
 ERX-AUDIO-24 Module; TX-AUDIO-24 Module;
 TX-AUDIO-24/AE Module

ExpressPCB — www.expresspcb.com
 RX-AUDIO-24 Support Printed Circuit Board;
 TX-AUDIO-24 Support Printed Circuit Board

Fender Musical Instruments — www.fender.com
 Fender Stratocaster; Fender Princeton Reverb Amplifier

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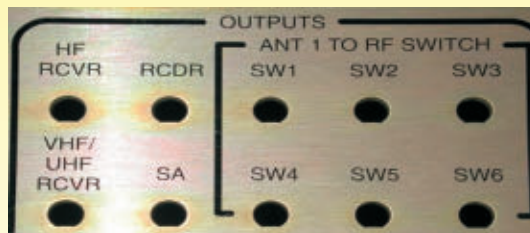
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BY L. PAUL VERHAGE

YOUR OWN MICRO DATALOGGER

AFTER DESIGNING AND TESTING A SIMPLE BalloonSat flight computer last time (the BalloonSat Mini), I felt there was a need for a larger and more powerful version for beginners. To keep its price low, this new flight computer uses another PICAXE like the BalloonSat Mini. I call the result the BalloonSat Easy.

The PICAXE-08M is a nice little microcontroller. In a lot of ways, it's like popcorn — small, cheap, and very addicting for small projects (will the PICAXE-08M soon replace the 555 as the world's most popular IC?). However, it does have a down side — its limited memory. With only 256 bytes of memory for program and data, the PICAXE-08M is a limited datalogger. If you write tight code, you might get 190 bytes of data storage which is enough for a beginner's BalloonSat. However, with at least a pound of maximum payload weight, a BalloonSat can carry a lot of data-rich experiments. So, unless you want your BalloonSat to carry a dozen BalloonSat Minis, you'd better

use something larger than a PICAXE-08M. After a little research on the PICAXE forum, I found an answer in the PICAXE-18X and the 24LC family I²C memory chip.

THE BALLOONSAT EASY

Here's the components you'll need to construct a BalloonSat Easy:

- 18-pin DIP socket
- PICAXE-18X
- Eight-pin DIP socket
- 24LCXXX I²C EEPROM memory *
- LM2940 voltage regulator (TO-92)
- 22 μ F tantalum capacitor
- 1,000 μ F capacitor **
- 1K 1/4W resistor

- 4.7K 1/4W resistor (qty 3)
- 10K 1/4W resistor (qty 2)
- 22K 1/4W resistor
- 1N4001 diode
- Reed relay ***
- Three-pin straight headed (qty 2)
- 3 x 3 receptacle
- LED
- Nine-volt battery snap
- Female 1/8 inch mono receptacle
- Male 1/8 inch mono jack
- Subminiature toggle switch

Notes:

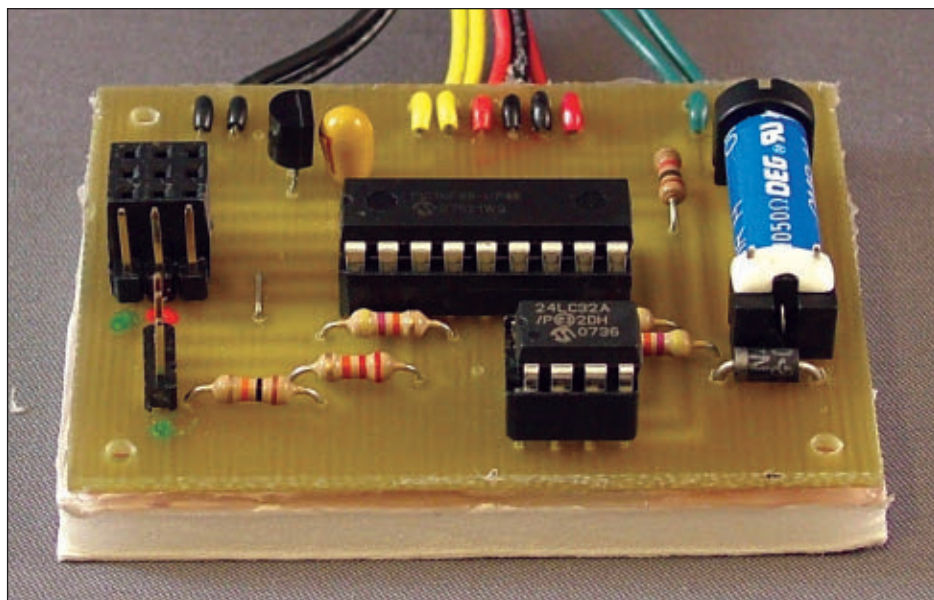
* The memory chips that work with the PICAXE-18X and their storage space are:

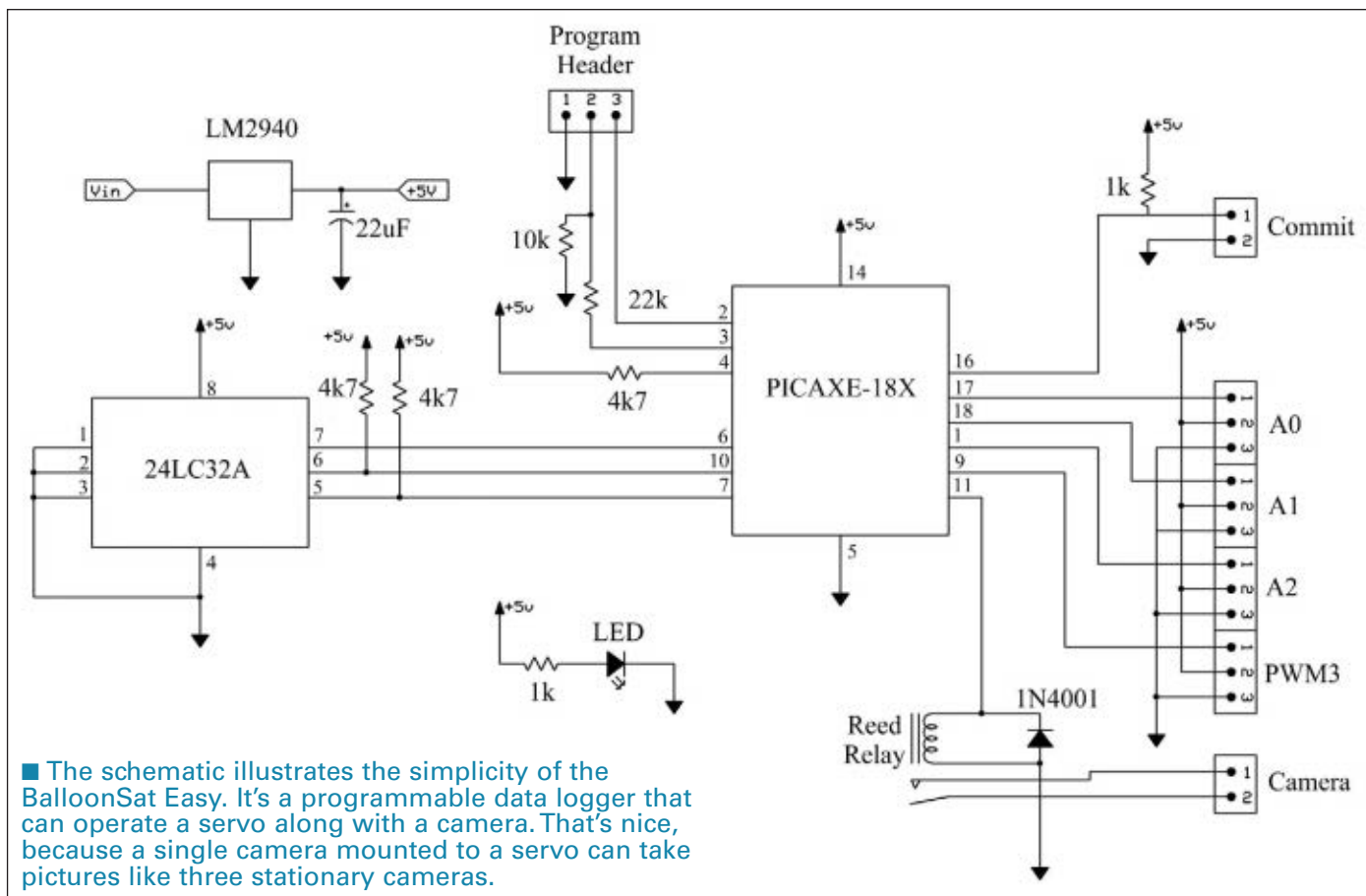
24LC32A	2 KB
24LC65	4 KB
24LC128	8 KB
24LC256	16 KB
24LC512	32 KB

**** If the BalloonSat Easy will drive servos, then this larger capacitor is needed (it must have a 0.2 inch spacing between the leads).**

*** The relay is a RadioShack 275-232, five volt reed relay (or its equivalent).

■ How about an inexpensive BalloonSat flight computer with three analog voltage inputs, a servo output, camera relay, and kilobytes of data storage? You could have yourself a real nice time in near space with that stuff.





The BalloonSat Easy PCB (printed circuit board) is easier to assemble if you start with the low lying components first. Therefore, assemble the BalloonSat Easy by first inserting and soldering the three jumper wires. The most convenient way to make them are to cut leads of resistors. Bend them into the proper sized staple shape before trying to insert them into the PCB.

Next up are the diode and resistors. The diode protects the PICAXE from EMF kickback when the relay shuts off. I don't suppose there's much of a kick with this small of a relay, but I'd hate to take the risk at 100,000 feet. So, think of the diode as making the BalloonSat Easy just a little more bullet-proof.

The 22K and 10K resistors in the upper left are for the programming header. The 4.7K resistors are pull-ups for the I²C memory and the PICAXE-18X reset pin. To prevent accidents from occurring during the mission, there's no switch to reset the PICAXE. The other 10K resistor is the

pull-up for the Commit Header, which is described later.

Next, install the two IC sockets. Electrically their orientation is irrelevant, however, their markings indicate the proper orientation of the PICAXE-18X and the I²C memory. So, orient them as illustrated in the **placement diagram**.

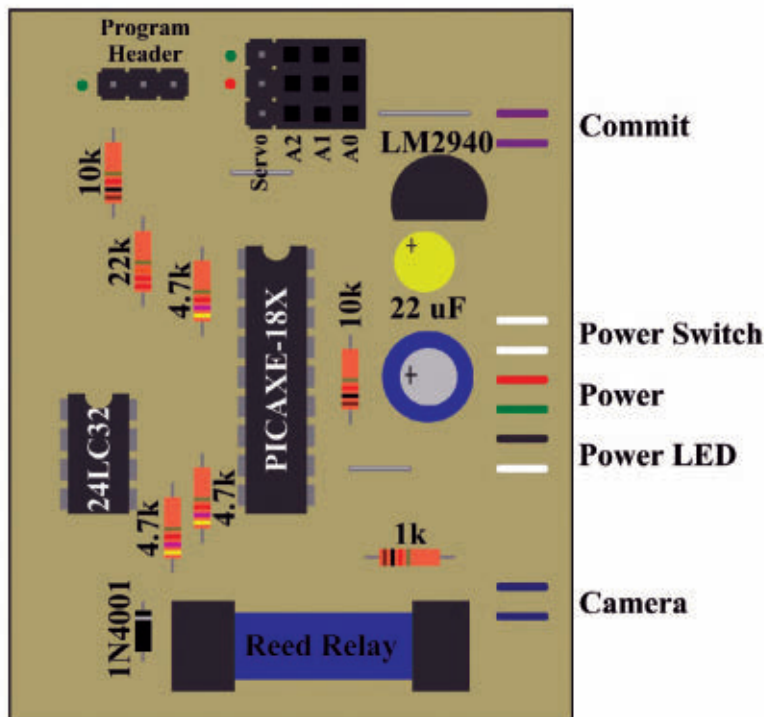
Install the relay, the 22 μ F capacitor, the 1,000 or 2,200 μ F capacitor (if your BalloonSat Easy will operate servos), and the voltage regulator. The relay can't be inserted backwards, but the other components can. So, watch their orientation because the BalloonSat Easy won't work with them installed backwards.

Now that the components have been soldered to the PCB, it's time to add the cabling. All the cables are routed through the strain relief holes near the edge of the PCB before they are soldered to the PCB. Drill the strain relief holes 1.5 mm in diameter so they are large enough for #24 AWG wire.

The first two cables are the

battery snap and the camera cable. These cables remain inside the BalloonSat airframe and are not routed to the airframe. A nine volt battery snap is sufficient for the BalloonSat Easy in most cases. However, if the mission requires a lot of servo work, you'll want to replace the nine volt battery snap with a six volt battery pack. A four "AAA" battery pack works well for this, but does raise the final weight of the BalloonSat. In the parts placement diagram, the positive lead of the battery cable is colored red and the negative is colored green. It's best to terminate the camera cable in some type of electrical connector. That way, the camera doesn't dangle from the end of the cable while the BalloonSat is under construction. I like using Dean's Micro Plugs for this purpose. A bag costs less than \$3 and contains two sets of connectors; enough for the BalloonSat Easy and its camera.

The remaining three cables are the power switch, the LED power



■ Use this image for the placement of parts. As the article explains, a cable of 10 wires connects to the PCB (as shown on the right side of the board). This cable allows you to position components like switches on the exterior of the BalloonSat airframe.

when this Commit Pin is removed from the Commit Header and begin recording data. This way, a BalloonSat containing a BalloonSat Easy can be started before the launch and not waste memory storing data before launch.

In the parts placement diagram, I've placed red and green dots at locations that indicate +5 volts and ground. Use enamel model paint and a tooth pick to apply the dots on the PCB. Set the PCB aside to dry so the paint isn't smeared before it dries.

This completes the assembly of the BalloonSat Easy. However, before you snap in the PICAXE and launch it, let's perform the function testing. Double-check all the soldered connections that there are no solder bridges, that all the soldered pads are well soldered, and that there are no gaps around the connections. Then, measure the continuity between the positive and negative leads of the battery snap. There should be none with the power switch flipped on or off.

Now attach a battery (but don't insert the ICs yet) and power up the flight computer. The power indicator LED should light up. Then, set the multimeter to measure DC voltage and check the voltage between pins 5 (test with the black test lead of the multimeter) and 14 (test with the red lead) of the 18-pin socket. There should be positive five volts (give or take 0.25 volts) on pin 14. Then, check that there is positive five volts between pins 14 and 4 (the PICAXE-18X reset pin). Next, measure across pins 5 and 16. Without the Commit Pin in place, it should measure five volts across these two pins. With the Commit Pin in place, the voltage between these pins should measure zero volts.

The next test involves measuring

indicator, and the commit header. They route important controls to the exterior of the BalloonSat airframe — this way, the BalloonSat can be powered up and its mission started without having to open its hatch. Of the three cables, only the LED power indicator cable is polarized. In the parts placement diagram, the LED's positive (anode) wire is white and the negative (cathode) wire is black. The power cable terminates in a subminiature toggle switch, the power indicator cable terminates in an LED, and the commit header cable in an 1/8 inch mono jack receptacle. I'd recommend making these three cables around six inches long — unless your BalloonSat is unusually large (BalloonSats of Unusual Size; BOUS).

Before attaching the switch, mono-receptacle, and LED to the end of their respective cables, slide heat shrink over the wires. The switch and mono-jack receptacle have pierced leads for attaching wires. So, bare the ends of the wires, insert them into the openings in pierced leads, twist them tight, and solder. The leads of the LED connect directly to the wires in the power indicator cable. So, cut the leads of the LED to half their

length and tin them. Strip the last half inch of the wires in the LED cable, twist them tight, and tin them. Place the positive wire in contact with the anode lead of the LED and heat them with a soldering iron. The solder in the lead and wire will fuse together, uniting them. Repeat the process for the negative wire and the cathode lead of the LED. After the connections cool, slide the heat shrink over the soldered connections and shrink.

The last assembly step is for the Commit Pin (which shorts out the Commit Header). The pin is an 1/8" mono jack with its tip and base shorted together inside the jack housing. Unscrew the jack housing and solder a wire across its base and tip connections with a four inch long wire. Double over the shorting wire so it extends out through the end of the housing. Squirt a little hot glue around the soldered connection of the jack, pass the doubled-over wire through the jack housing, and screw on the housing. After the initial shot of glue cools, squirt some more hot glue into the back opening of the housing. After the Commit Pin cools, tie a red ribbon to the wire loop protruding from the jack housing. The PICAXE-18's flight program will detect

the voltage in the I/O ports. In the diagram of parts placement, the red dot marks the +5 volt row of receptacle pins and the green dot marks the row of ground receptacle pins. Use cut resistor leads and insert them into a +5V and ground receptacle pin and verify that the proper voltage (within 0.25 volts either way) is present.

The final voltage test verifies the I²C memory socket. With power applied, you should measure +5 volts between pin 8 and pins 1 through 4 (in other words, pins 1 through 4 are grounded). Since pins 2 through 4 are grounded, the I²C memory has an address of 000 (which you'll see in the sample flight code). Now the BalloonSat Easy is ready for its PICAXE-18X and I²C memory.

Consult the PICAXE Guides (they come with the free PICAXE Editor) for information concerning the programmer and serial programming cable. Assuming you're ready with a programming header and editor software, test the programming connection and your programming cable using this code snippet.

DEBUG

The debug screen should pop-up with a single report showing that all RAM memory locations are zeros.

Use the following code snippet to test the servo connection. Be sure to consult the paint marks on the PCB for the proper orientation of the servo connector.

```
Servo_Test:
  pause 1000
  servo 3,100
  pause 1000
  servo 3,200
  pause 1000
  goto Servo_Test
```

The servo will swing back and forth every second.

Use the following code snippet to check the memory:

■ The 434 MHz receiver (WRL-08950) that I selected for the Near Space Swarm. This complete receiver is available from SparkFun for \$6.

```
` set memory speed to 400 kHz
` and one word records
i2cslave %10100000,i2cfast,
  i2cword
```

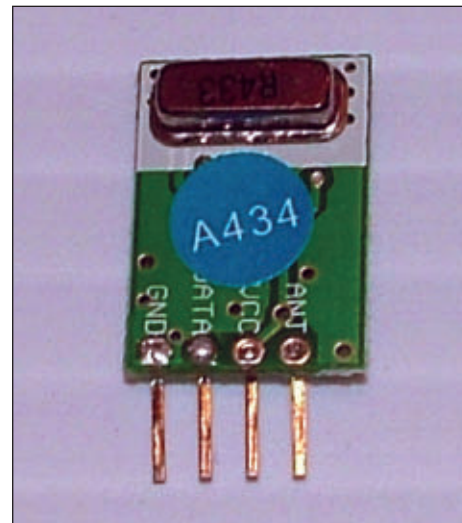
```
Record_Data:
  low 0 `unwrite protect memory
  ` write 50 word length record
  for B2 = 1 to 100 step 2
    W0 = B2 * 2
    writei2c B2,(B0,B1)
    pause 10 ` wait 10 ms
  next ` continue writing data
```

```
Download_Data:
  ` padding to protect
  ` first record
  srtxd ("Begin",cr)
  for B2 = 0 to 100 step 2
    ` read the recorded record
    readi2c B2,(B0,B1)
    ` serial out the data record
    srtxd (#B0,",",#B1,CR, LF)
  next
```

The program will write 100 bytes (50 words) of data to memory and read it back. After you download the program, shut off the flight computer and open the PICAXE terminal program which is located under the PICAXE drop-down menu. Be sure it's set for 4800 baud and then power up the flight computer. Then, start up the BalloonSat Easy and you should see a stream of digits like this if the memory chip and PICAXE are properly talking properly together:

```
Begin
0,2
0,6
0,10
```

I recommend attaching the LED, power switch, and commit header receptacle to a plastic panel. This way, the control panel can be bolted to the airframe as it was described for the BalloonSat Mini. I also



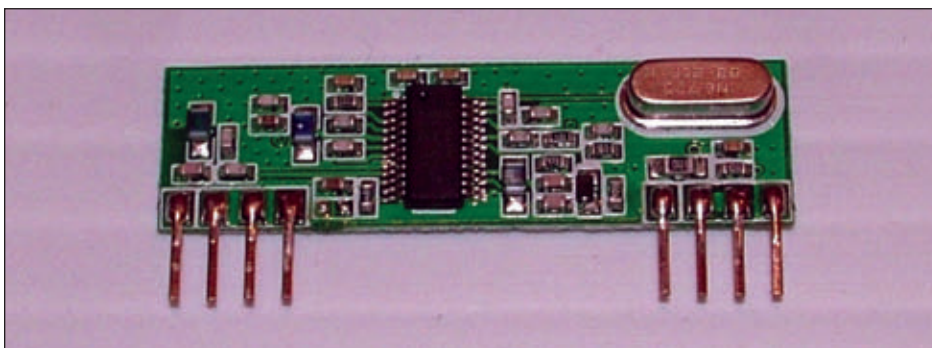
■ The matching 434 MHz transmitter (WRL-08946). It's much smaller because it's easier to talk than it is to listen. It too is available from Sparkfun.com for \$4.

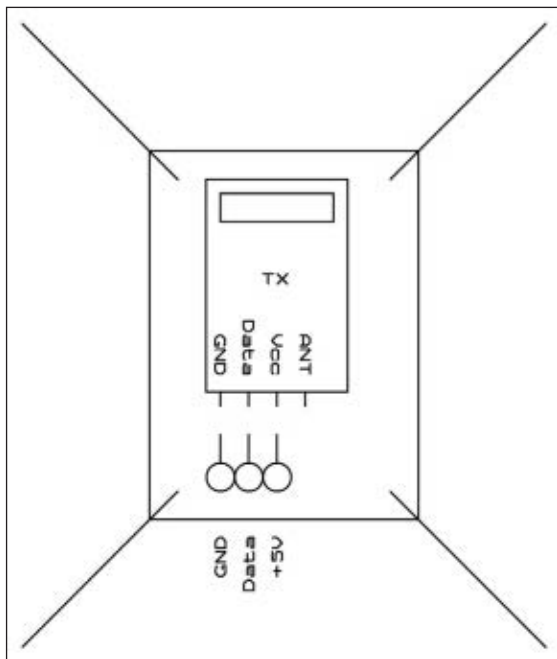
recommend covering the bottom face of the PCB in a sheet of 1/4 inch thick Foamcore to protect the solder pads beneath the PCB from accidental shorts.

Now that the BalloonSat Easy is complete and quality checked, it's time to start writing flight code and building your next BalloonSat. You'll find sample flight code on the *Nuts & Volts* website (www.nutsvolts.com) that you can use as a first step. The file is called BalloonSat Easy Mission.bas.

THE BALLOONSAT EASY KIT IS AVAILABLE

The BalloonSat Easy V2.0 kit is available on the **NearSys.com** website, if you would rather not make your own PCB and purchase the individual components. The kit is





■ Just like the receiver, solder the radio, power, and communication cable, and the antenna to the PCB.

the Near Space Swarm). BalloonSats are designed with particular tasks in mind that tend to be simple and limited. However, if their actions can be coordinated, then a swarm of BalloonSats acts collectively by recording their data simultaneously. Or, perhaps one BalloonSat could initiate an experiment for a second BalloonSat to record. Or, perhaps the synchronizing authority for the BalloonSats could be the near spacecraft with its onboard GPS receiver. Then, all the actions take place at

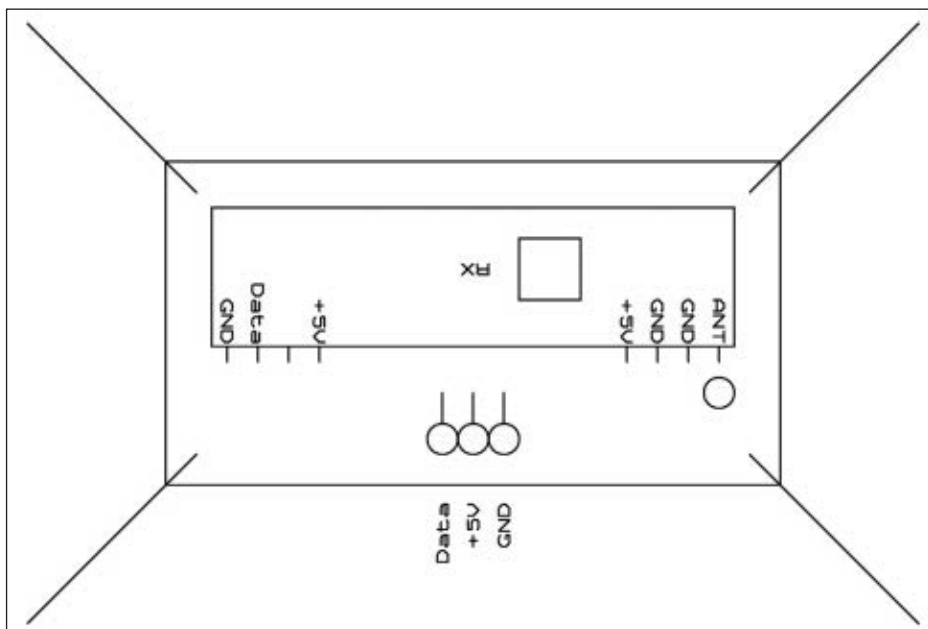
complete except for the serial EEPROM memory chip, since many options are available from places like **HVWTech.com** for just a few dollars. The BalloonSat Easy kit costs \$30 plus \$4 shipping and handling.

ACCESSORIZING BALLOONSAT FLIGHT COMPUTERS

Because of their small size and simplicity, BalloonSats make an ideal test of a Near Space Constellation (or

specific altitudes and times. The combination is synergetic and yields more thorough data collection when everyone plays their part.

Because of their simplicity and affordability, I chose the 434 MHz transmitter and receiver boards from **Sparkfun.com**. I designed a PCB to support the transmitter and receiver that makes it easy to interface them to near space flight computers. You can see from the bottom copper pattern and top silk patterns that the PCBs are equally simple. These files are also available



on the *Nuts & Volts* website.

THE TRANSMITTER AND RECEIVER

I used to rip toy R/C cars apart for their radios. But after Barry Nye, the Technology Guy of the Boise Robotics Group introduced me to these radios, I've stopped my old habits and picked up a couple of new ones.

I just fold the leads of the radios to a 90 degree angle and solder the transmitter and receiver to the PCB. I use #24 stranded wire to create the interface cable for the PCB. Each wire solders to a PCB pad and then passes through the strain relief holes, creating a single cable for the transmitter and receiver. The end of the cable terminates in a single row header of three pins. The header lets me snap the cable directly into the expansion port of the flight computer inside the near spacecraft or BalloonSat. To terminate the cable in a three pin header, strip back 1/4 inch of insulation from the ends of each wire in the cable and tin them. Slide a piece of heat shrink tubing over each wire so it can be used later to insulation the connections in the header. Next, tin the short pins of the header. Now, lay a tinned wire from a radio PCB against the appropriate tinned header pin and tap them with a hot soldering iron.

After the solder has fused the two together, remove the soldering iron and let them cool. Repeat the process for the other two wires and header pins. When all three connections have cooled, slide the heat shrink over the connections you just made and shrink the tubing. Now when you plug the header into an expansion port, the radio boards get power and ground and they can exchange data with the flight computer.

The four corner pads in the PCBs are for the ground elements of the antenna. Use a thin gauge, single

■ You just need to solder the radio, power, and communication cable, and the antenna.

■ A BalloonSat Mini and BalloonSat Easy connected via a radio link. Doesn't this swarm look vaguely like two neurons?

stranded wire for them. You might as well leave the insulation on the elements, especially if the insulation is brightly colored, making the antenna wires more visible. The antenna itself is a single wire of the same type as the ground elements. All five elements are 6-1/2 inches long and should be terminated with a small loop of wire. That way, they are less of an eye poking hazard.

TRANSMITTING DATA

Sending data is very simple with this transmitter using this code:

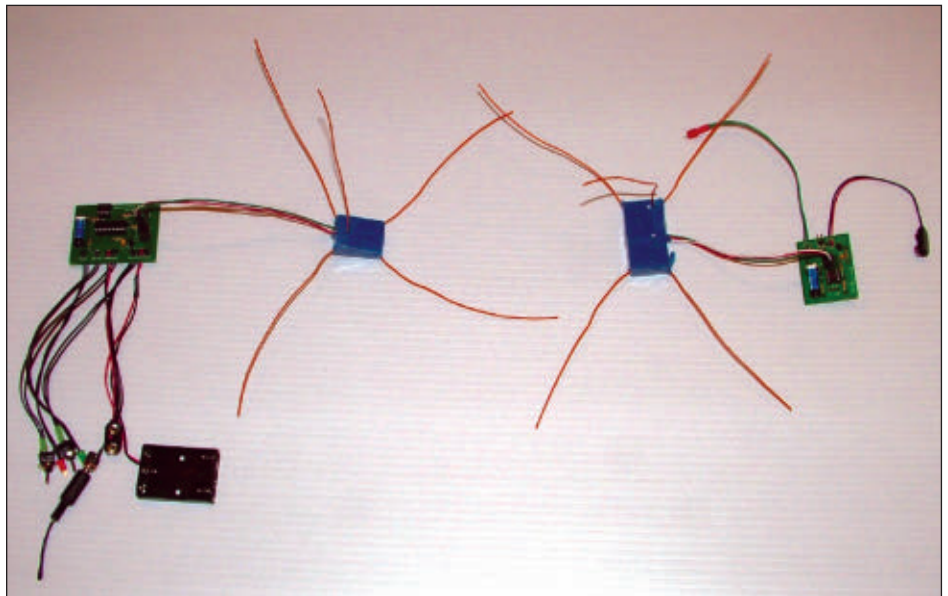
```
symbol Command=B1
symbol Check=B2
symbol TX=4
symbol MyID = 51 'personal ID
Check = Command * MyID
serout TX,N2400_4, (170,170,170,
"D",Command,MyID,Check, "D")
```

The variable Command is the one byte command I want to send to the other BalloonSats on the mission. The variable MyID is an identification number I give to every module on the near space vehicle. The variable Check is a very simple checksum that identifies some bad packets. The 170s that are first transmitted from a binary pattern of 10101010. That starts the transmitter by sending an even mix of 1s and 0s, and improves the reliability of the transmission link. The D indicates that data is being sent. The receiving BalloonSat will do something similar, but using the SERIN command:

```
serin RX,N2400_4, ("D"),
Command,ItsID,Check
```

The receiver waits for the D and then reads the next three bytes. After verifying that Check = Command * MyID, it acts on the value in Command.

This code worked well during a ground test, however, I have a concern using this code because a



PICAXE-08M does not have a time-out option with the SERIN command. So, if the transmitter fails for some reason, the BalloonSats are hanging there dead in the water (vacuum). To prevent this, I'll eventually experiment by setting the transmitter's data pin high for a few seconds before transmitting data. Then, the BalloonSats can check to see if its receive pin is high before it begins listening for a command. If they don't detect a high on their receiver pin within an allotted time, the BalloonSats will assume the

transmitter is dead and will begin operating independently.


With a command one byte wide, 256 commands can be sent. That's currently overkill since I just want to tell every BalloonSat in the swarm when to record data. I'll have to see what the near space swarm can do with more commands. Perhaps some day a swarm of near space PICAXE-08Ms will return to earth far more intelligent than they were when they left.

Onwards and Upwards,
Your near space guide **NV**

BUDGET ROBOTICS

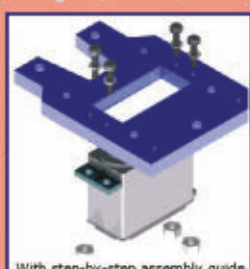
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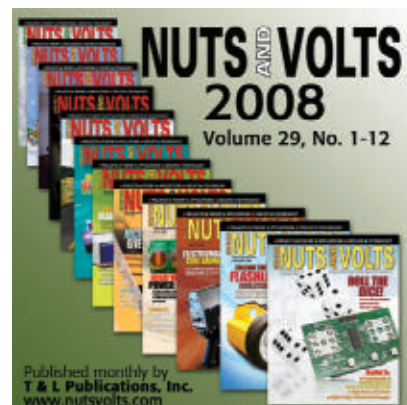


Given the modern economy, it pays to know how to repair everyday appliances, and this book provides an excellent overview of how to diagnose and repair everything from hot water heaters to microwave ovens. The book is highly illustrated, and the sections on safety and tool selection are especially helpful for first time do-it-yourselfers.

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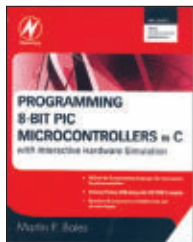
ELECTRONICS

Programming 8-Bit PIC Microcontrollers in C by Martin P. Bates

Step-by-step, practical instructions on how to program PICs in C, with no prior experience necessary!

PIC Microcontrollers are present in almost every new electronic application that is released from garage door openers to the iPhone. With the proliferation of this product more and more engineers and engineers-to-be (students) need to understand how to design, develop, and build with them. Martin Bates, best-selling author, has provided a step-by-step guide to programming these microcontrollers (MCUs) with the C programming language.

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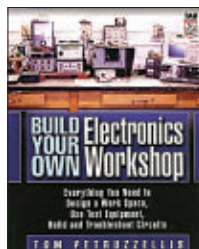


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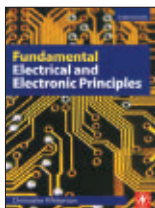


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by C R Robertson

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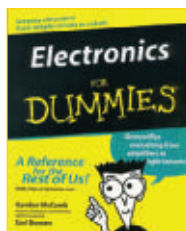


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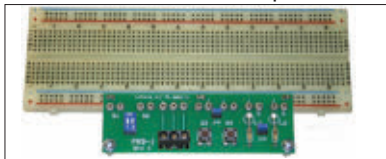


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by Joe Pardue

As talked about in the
Nuts & Volts June issue,
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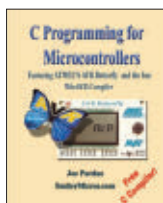
This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

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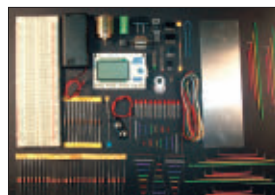
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As seen on the March 2009 cover



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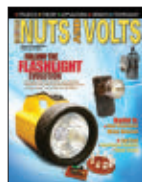
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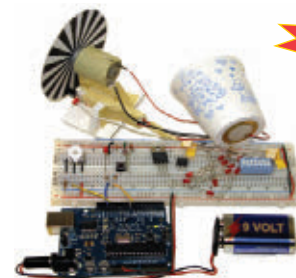
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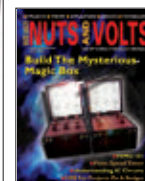
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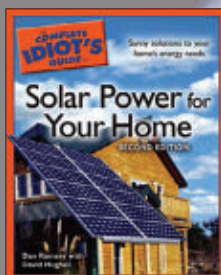
ALTERNATIVE ENERGY SECTION

The Complete Idiot's Guide to Solar Power for Your Home

by Dan Ramsey / David Hughes
Publish Date: May 2007

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Build Your Own Electric Vehicle

by Seth Leitman, Bob Brant

Publish Date: October 10, 2008

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by Jamil Shariff

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Run Your Diesel Vehicle on Biofuels A Do-It-Yourself Manual

by Jon Starbuck, Gavin D J Harper
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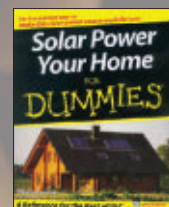


Solar Power Your Home For Dummies

by Rik DeGunter
Publish Date: Dec 2007

This friendly, hands-on guide is packed with tips for making your home more energy-efficient through solar power—and helping the planet at the same time. You'll see how to survey your home to determine your current household energy efficiency and use, and evaluate where solar power would best benefit you. You'll also calculate what the return on your investment will be before you make any decisions.

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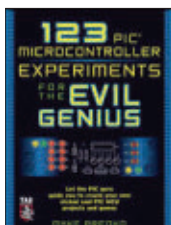
123 PIC Microcontroller Experiments for the Evil Genius

by Myke Predko

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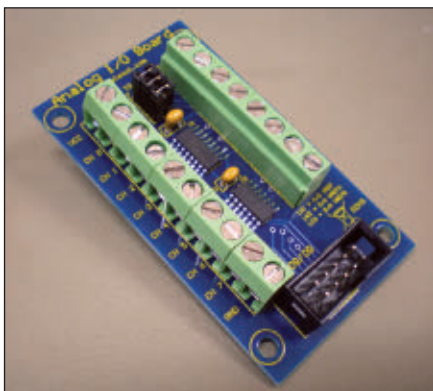
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ELEXOL'S ANALOG I/O BOARD PROVIDES ANALOG INPUTS/OUTPUTS VIA A SPI CONNECTION TO THE I/O 24 RANGE



The Analog I/O Board from Ortech Education Systems is an accessory board that allows

the implementation of an analog interface to Elexol's existing I/O 24 Range. The Elexol I/O 24 Range consists of Ether I/O 24 R, Ether I/O 24 DIP R, USB I/O 24 R, and the USB I/O 24 DIP R.

The Analog I/O Board incorporates an eight channel 10 bit analog-to-digital converter and a 12 bit Digital-to-Analog Converter with two buffered outputs. The reference voltages for the A/D and D/A converters are all accessible via the screw terminal connections and a set of jumpers have also been provided to connect the reference voltages directly to 5 VDC.

Applications

- Home/industrial automation
- Remote monitoring systems
- Any other use where an analog input or output is required

Features

- Eight Channel 10 bit Analog-to-

Digital Converter (MCP3008)

- 12 bit Digital-to-Analog Converter with two buffered outputs
- Easy connection to analog inputs/outputs via screw terminal blocks and I/O range via 10 way IDC cable
- Compact measurements 40 x 72 x 20 mm (DIN Rail mountable with adaptor)

Benefits

- Provides the existing I/O 24 Range with an analog interface.
- Easy software implementation through Elexol I/O 24 SPI Protocol

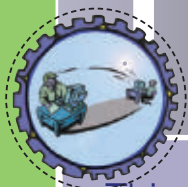
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TECH



FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams* should be computer generated and sent with your submission as an attachment.

QUESTIONS

To be considered, all questions should relate to one or more of the following:

- ① Circuit Design
- ② Electronic Theory
- ③ Problem Solving
- ④ Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).

■ Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.

■ No questions will be accepted that offer equipment for sale or equipment wanted to buy.

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ANSWERS

■ Include in the subject line of your email, the question number that appears directly below the question you are responding to.

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■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

Mylar Speakers

I would like to get information on Mylar speakers and their theory of operation. I need to replace a Mylar speaker installed in a Panasonic cordless handset telephone. Can a regular dynamic speaker replace a Mylar?

#5091

James Brendage
Orangevale, CA

PIR Motion Detector

I purchased an inexpensive PIR motion detector and did not notice it said "for incandescent only" in small print. It works great with an incandescent lamp, but not well with an inductive load such as a relay or fluorescent lamp. Is it feasible to alter one of these to operate other loads? If so, how?

#5092

Steve Gunsel
Medina, OH

DC Power Transformer Question

I have five table-top water fountains which I want to run constantly. They are designed to use two AA batteries for each fountain, which is impractical.

1. What plug-in DC power transformer (voltage and amps) can I substitute for the 10 batteries to power all five devices?

2. How should it be wired — in series or parallel?

#5093

Garry Smith
Indianapolis, IN

>>> ANSWERS

[#1093 - January 2009]

Video Adapter

I would like to feed the modulated video output from my DVD player to a SVGA video monitor. Other than stripping the modulation from the signal, I'm not sure what to do next.

A typical DVD player has composite video output on an RCA jack mounted on the back. You can use a composite video to VGA converter to display on your SVGA monitor. Search on "composite video converter, 40-889" to locate the model I looked at. A less expensive model can be found by searching for "Ultra Small Video to VGA Converter." Omit the model number to locate other models. The adapter box contains enough circuitry to require an included wall-wart power supply. The 40-889 converter has a FM BNC video input. So, you need an M BNC to RCA adapter, along with an RCA jumper cable from the DVD player to the adapter to the 40-889 converter. The 40-889 VGA output will drive your SVGA monitor.

Dennis Crunkilton
Abilene, TX

[#1096 - January 2009]

Logic Analyzer

I have a LEADER Model 300 DMM/scope with logic analyzer. I need

help/info to build an interface circuit that would allow me to use the eight channel logic analyzer.

I recommend against building your own probe because you may encounter insurmountable obstacles due to parts availability. I do recommend, however, to go out on eBay and either find the probe or find a repairable one. The service manual for the LEADER Model 300 is available at Manuals Plus for about \$40, which is somewhat typical. A logic analyzer probe sells for about \$20-\$200 on eBay. Consider buying a Tektronix 1230 or 1241 logic analyzer instead, which are much better instruments and can be had for as little as \$30, since labs are shutting down due to the economy. I also like the HP1631D, which is a 50 MHz, two channel scope mated to a logic analyzer and it has the pods (probes) attached. I've seen the HP1631D sell for as little as \$20. Interestingly, probes tend to be somewhat expensive and harder to get, probably because fewer functional ones have survived.

**Walter Heissenberger
Hancock, NH**

**[#2093 - February 2009]
Power Pac for HO Railroad**

Does anyone know of any plans for controls to run several trains simultaneously on the same line, independently of one another?

There is a standard model train controller that does what you are requesting — running several trains on the same track independent of each other. It is called DCC (Digital Command Control). This system replaces the variable DC voltage that was applied to the track to control the speed and direction of the train on the track. DCC uses a square wave AC constant voltage on the tracks. The square wave is FM modulated with digital information in packet form so that specific engines can be given specific commands independent from the other engines. Each engine is modified by adding a small decoder circuit between the wires coming from the wheel pickups and the electric

motor of the engine. Each engine is assigned a unique number (usually the last four digits of the engine #). The engine direction and speed can be controlled as well as headlights, ditch lights, mars lights, and if the engine had a sound module, it can control the sounds from the engine. The number of engines that can be controlled on one track depends mainly on how much current the controller is designed to produce. They range from one amp up to 10 or 20 amps. Boosters are also available to increase the power capability of the system. There are schematics available on the Internet for home-built controllers but the complete units available on the market are reasonable in price and have many features that would be difficult to reproduce at home such as handheld throttles that contain the complete circuits with LCD displays to show speed, direction, and engine number with buttons for the lights, whistle, bell, engine sounds, etc. Most local hobby shops carry the various brands of DCC controllers and decoders for the engines. The controllers range from around \$75 on up to \$500+ for wireless ones with all the bells and whistles. Decoders for the engines run around \$25 to \$40 each, depending on features included and power capability. DCC is an industry standard so components from one company will work with ones from a different company.

**Dennis Hall
Maple Grove, MN**

**[#2094 - February 2009]
Regulators or Zener Diodes?**

Many of us use the regulator devices 7805, 7812, etc., in our designs. What is the difference between these and using zener diodes? When do you use a low resistance resistor in series with these devices?

The difference between the zener and three-terminal regulator (7805, LM340) is with the method of achieving regulated voltage. The zener is a shunt regulator and the 7805 is a series regulator.

The shunt regulator requires the power source provide maximum load

current at all times, with the zener absorbing whatever load current that the device (operating at constant voltage) does not require at the time.

The series regulator is an integrated circuit that provides the required load current to maintain a constant output voltage. The current drain on the power source is that required by the device operating at constant voltage plus a small current to operate its internal circuitry (about a milliamp).

Take a look at www.national.com/an/AN/AN-103.pdf for a good description of the "guts and feathers" of a three-terminal regulator (LM340 is the National developed version of the 78XX regulator designed by Fairchild).

I am not sure what you're asking about the low resistance in series with the regulator. The zener requires the resistor between it and the power source to be sized such that the current passing through it be more than the maximum required by the circuit (which could be a low resistance if the voltage source is very close to the zener voltage). Having a zener voltage that is close to the supply voltage causes large current variations (and possible heating concerns) as the supply voltage changes.

**Denis Kuwahara
Port Orchard, WA**

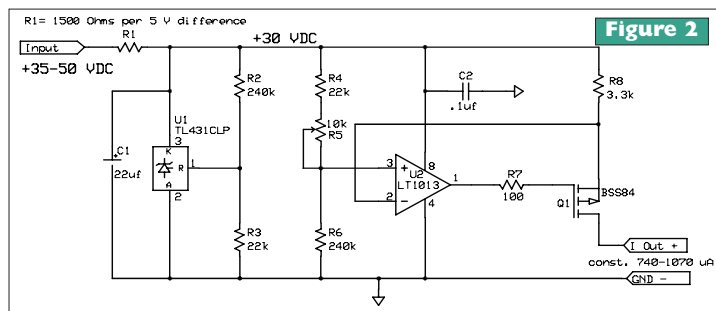
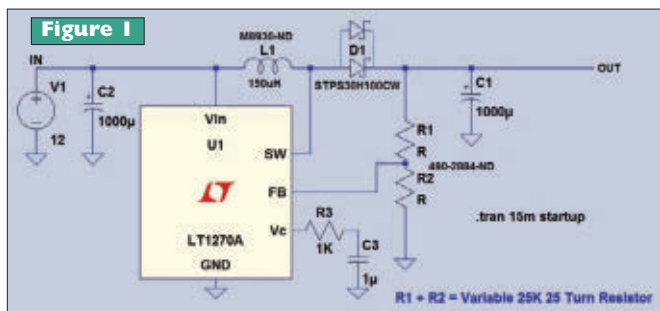
**[#2095 - February 2009]
Auto 12V to Laptop 19V Power**

I'm looking for a circuit that can boost the 12V in a car to 19V, enough to run two laptops (batteries removed). It will have to provide at least 100W. I bought one off eBay but it is unstable with my laptops (shuts down randomly).

#1 Before you buy a new power supply, you might check if the instability in the one you purchased is due to minimum load requirements or changing load.

Many regulated supplies have an automatic shut-down feature when current drops too low, as well as when it is too high. Try placing a small, steady load, such as a one ampere, 24 volt lamp (or two 12 volt, one amp car light bulbs in series) in parallel with the two laptops.

It is also possible that high



frequency current from the laptops is getting into the power supply; try capacitors across the supply line to suppress transients. It might be necessary to use a 4,000 μF capacitor in parallel with a 1 μF tantalum and 0.1 μF ceramic capacitor because the larger capacitors lose effective impedance at higher frequencies.

It would also be useful to place some inductance in series with each laptop so as to isolate glitches in one from the other.

Bart Bresnik
Manasfield, MA

#2 You don't have 12 volts in a car. When a car starts, the amp draw of the starter lowers the voltage to as low as 10.5 volts on a cold winter morning, followed by the alternator recharging the battery at 14.5 volts. I hope you see why the adapter you have is unstable. The solution I use is the reliable 12V DC to 110V AC converter. This costs less than \$30 and you use your laptop AC adapter which also gives some filtering to make sure you are getting proper voltage for your equipment.

Steve Benson
New Castle, IN

#3 I have been using the circuit in Figure 1 to power my HP Pavilion ze1210 Laptop in my car for some time now. It works quite well and never even gets warm. The current drain is maximum 3.95 amps but average current is about three amps. I believe the circuit will power two laptops without any problem. All the parts were obtained from Digi-Key except for the Schottky diode which was obtained from www.bgmicro.com. The price of the LT1270A is \$16 from Digi-Key and it will handle up to 10 amps (120 watts). The two 1,000 μF

caps are low ESR types from Digi-Key, part number P11223-ND. Total price for all the parts is approximately \$25. Connect the input to a 12 volt DC source and adjust the voltage at the output for 19 volts. A suitable heatsink is also available from BGmicro, part number ACS1415 for 49 cents.

Chuck Irwin
Hendersonville, NC

[#2096 - February 2009] Constant Current 30 VDC

I need a schematic for a 30 volt DC power supply running at a constant current of 800-900 microamps, adjustable.

A precise, constant, current source is easy to build. Almost any raw supply voltage in the range of 35 to 50 volts can be used. In Figure 2, the supply current is about 3.5 mA. A TL431 precision reference stabilizes the supply voltage to about 30V as a shunt regulator. The reference voltage of approximately three volts is generated through a divider and compared against a voltage generated by the load current in R8. A PMOS transistor then serves as an output stage while R7 prevents high frequency oscillation in this stage. The gate current and the currents flowing into the op-amp inputs are miniscule, resulting in an accurate output current.

Walter Heissenberger
Hancock, NH

[#2097 - February 2009] Sensing AC Fan Motor

I'm looking for an easy way to sense when my home AC/heater fan is running (110 volts).

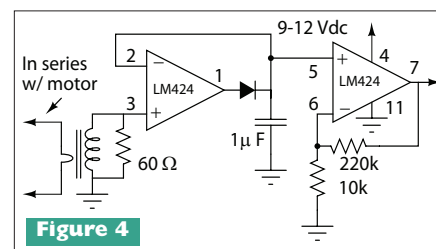
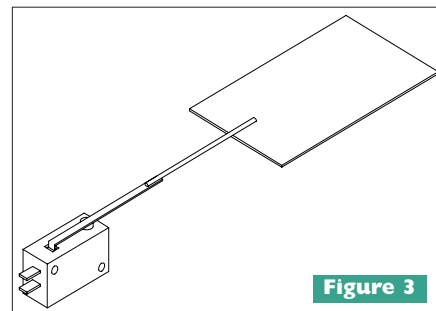
I have an electronic timed pump air freshener that I want to spray into the AC/heater plenum ONLY when the fan is running so it will carry the

fragrance throughout the house.

An easy way to sense airflow is with a flag attached to a microswitch, for example, Honeywell V3-23-D8 in the Jameco catalog. Figure 3 shows an extension rod and aluminum flag attached to the microswitch actuator. The extension needs to be long enough and the flag large enough to snap the switch closed in the flowing air. It must be light enough to snap back off with no air flow.

Otherwise, a more complex solution is to use a CT (current transformer) to measure the current drawn by the motor. Triad Magnetics CSE187L-P from Digi-Key (at \$2.89) turns ratio primary to sense 1: 500, with a suggested burden resistor of 60 Ω outputs 110 mV/amp. A 1/4 HP motor draws approximately 2A; thus, 220 mVAC out of the CT with the 60 Ω burden resistor on the sense winding. Figure 4 shows a peak detector and gain of 22 stage to give about 6 VDC out for 2A in to the CT.

Dennis Crunkilton
Abilene, TX





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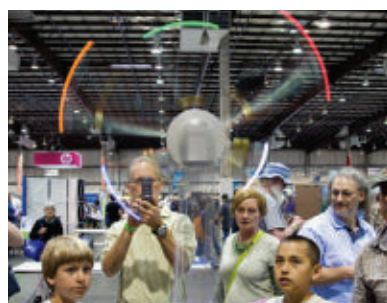
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320 x 240 Blue graphic LCD
5.7"

\$399 / Qty.1

Visual touch controller

CUTOUCH

CUBLOC module, Graphic LCD, and Touch Panel are fused into one product. With BASIC, you can create custom graphics and process touch input. With Ladder logic, real-time I/O and sequence processing can easily be implemented into your final product. With 82 I/Os, 80KB program memory and 2 RS232 hardware independent ports, there is plenty of room for your development.

PLC on chip with BASIC CUBLOC

The CUBLOC's unique multi-tasking RTOS runs BASIC and Ladder Logic programs side-by-side, allowing you to combine the flexibility of BASIC with the industry-proven power of Ladder Logic.

MODEL	CB220	CB280	CB290	CB320	CB380	CB405	CB405RT
FLASH	80KB	80KB	80KB	200KB	200KB	200KB	200KB
I/O	16+6	40	91	16+6	40	64	56
DATA	3K	3K	28K	7K	7K	110K	110K
RS232	2	2	2	2	2	4	4
PWM	3	6	6	3	6	12	6
ETC			RTC				RTC/16bit ADC

[Module Comparison Chart]

[CB405RT Spec.]

- ▶ 16bit ADC
- ▶ Package : 80 pin
- ▶ Flash memory : 200KB
- ▶ 8 channel 16 bit A/D
- ▶ 4 channel RS232 communication port
- ▶ Real time clock
- ▶ I/O port : 58
- ▶ Data memory : 110KB
- ▶ 6 channel 16 bit PWM



\$46 / Qty.1

New
CB405RT

COMFILE
TECHNOLOGY

550 Pilgrim Drive,
Suite K, Foster City,
CA 94404
• 30-Day Money-Back Guarantee

Toll-free : 1-888-928-2562
Visit www.cubloc.com
to see more products!



4 Channel RF Remote Control System

This set consists of two (2) self contained transmitters (Key FOBs) and one (1) receiver module that works in the 434 Mhz Industrial band. This is a complete stand alone remote control system. **No programming required.** Onboard encoders/decoder utilize KeeLoQ code hopping technology for maximum security. 4 buttons are provided on the transmitters and four separate output channels are provided on the receiver board allowing one system to control up to 4 different on/off functions. **Typical applications include: Garage Door Opener, Security Access Gate, Remote Camera Activation, Any application requiring remote on/off control.**



Item #
RXD4140-434 **\$19.95**



ESD Safe, CPU Controlled, SMD Hot Air Rework Station

What every shop or lab needs to deal with todays SMD designed circuit boards. OEM manufactured just for Circuit Specialists Inc., so we can offer the best price possible! A multi-technology assembly and repair station. A wide selection of nozzles are also available.

- CPU Controlled
- Built-in vacuum parts handling wand
- Air Pump: Diaphragm special-purpose lathe pump
- Capability: 23L/min (Max)
- Temperature Range: 100°C~480°C/212°F~896°F
- 15-Minute Stand-By temperature "sleep" mode
- Power: 110/120 VAC, 320 W maximum

Item #
CSI825A++
\$99.00



OVERSTOCK SALE CSI-2901 LEAD Free Soldering Station

Compatible with all lead-free alloy solder and standard solder. Excellent thermal recovery without a large increase in tip temperature. Utilize an integrated ceramic heater, sensor, control circuit and tip for greater efficiency, along with a highly dependable 24V output transformer. The effortless replacement of soldering tips makes for quick changes and the optional shutdown setting turns the unit off after 30 min. of idle time. Various tips are available at our Web Site!



Item #
CSI-2901
•Power Consumption: 70W
•Output Voltage: 24VAC
•Temp Range: 392-896°F
Reg Price \$59.00 **\$39.00**



One Dollar Upgrade !!

Wow! Now thats a lot for only a Dollar more!!

You get the CSI2205D DMM prefitted into our 45-1 Protective Case for only one dollar more than the price of the CSI2205D alone.

The CSI2205D Micro Control Unit auto-ranging DMM is designed for measuring resistance, capacitance, DC & True RMS AC voltage, DC & True RMS AC current, frequency, duty cycle and temperature, along with the ability to test diodes, transistors and continuity.

Regular Price \$59.00

The 45-1 case is ideal for transporting small electronics & other delicate items. **Regular Price \$29.00**

Item# CSI2205D-BUNDLE
\$88.00 if purchased Separately!
Save \$28.00!!!

\$60.00



SMD Resistance, Capacitance & Diode Checker



A very convenient & small tool for testing SMD (Surface Mount Device) components, for example chip type resistors, capacitors and diodes. In addition it has a continuity function. Complete with storage case, battery and extra tip set.

- Auto Scanning Mode/Auto Range
- Display 3 2&3digit (3000 counts)
- Over load protection
- DATA HOLD Function
- 'FUNC' key manually holds the current reading
- Low battery indicator
- Auto Power Off
- Power Supply: 3V Lithium Battery (CR2032) 1pc

Resistance Ranges:
300 3K 30K 300K 3M 30M Ohms

Capacitance Ranges:
3nF 30nF 300nF 3uF 30uF 300uF 3MF 30MF

Capacitance & Diode Check:
Buzzer sounds when <30 Ohms

Item #
MS8910

\$29.95



Temperature Controlled Reflow Oven



FUNCTIONS and FEATURES

- Microprocessor-controlled equipment.
- Direct PCB temperature measurement, improves accuracy and lessens damage or distortion.
- Five (5) temperature and time control points with automatic slope adjustment. Configurable to suit different solder paste and circuit boards.
- Two (2) default profiles suitable with most common solder paste specifications.
- Quick and easy resetting of control points for precise tuning of reflow profiles.
- Built-in safety feature of industry standard 0.01°C/s to 3°C/s rising slope.
- Fully digital panel controls and read-out of time and temperature for monitoring and ease of use.
- Highly compatible with lead-free applications.
- Valid Solder Area: 8.274 in x 7.486 in

Item #
HHL3000

\$949.00

ESD Safe SMD & Thru-Hole Rework Station



An SMD rework station & soldering station in one handy unit! Perfect for shops & labs dealing with todays SMD board designs. Comes with an

ESD safe soldering iron and a Hot Air Wand with 3 Hot Air Nozzles. A wide range of nozzles are also available.



Item #
CSI906

\$99.00

New Item!

Close Focus Small Spot Size
Infrared Thermometer TN01U

ZyTemp
A new way to measure temperature

Featuring spot-on, dual-laser aiming, the TN01U close-focus, non-contact IR thermometer measures the temperature of electronic components as small as 0.1-in. with pinpoint accuracy. Compact and lightweight, the instrument provides a large LCD and a bright dual-laser aiming system that allows for accurate aiming. Features include a measurement spot size of 2.5-mm in diameter at distances up to 18 mm, measurement range from -55°C to +220°C, (-67-428 deg F) an accuracy of ±2% of reading or ±2°C whichever is greater, a repeatability of ± 0.2°C, display resolution of 0.1°C, and a response time of 1s. Operating with two AAA batteries providing 18 hours of continuous use, the instrument measures



SPECIFICATIONS:

Measurement Spot Size: 0.1-inch (2.5mm) diameter at 0.7" (18mm) distance

Temperature Measurement Range: -67° to 428 °F (-55° to 220°C)

Accuracy: ±2% of reading or ±2°C (whichever is greater)

Repeatability: ± .2°C

Display resolution: 0.1°C

Response time: 1 second

Bright, built-in Class II dual-laser provides pinpoint aiming accuracy. Easy-to-read LCD display with built-in clock.

Emissivity (adjustable from 0.05 to 1.00) is preset for electronic component temperature applications

Back-lit LCD display, select °C or °F, Auto Off

Uses 2 AAA batteries providing 18 hours of continuous use

Weight and Dimensions: 4.5 oz., 1" x 6.7" x 1.6"

This is the most advanced infrared thermometer manufactured today providing fast, accurate, non-contact component temperature measurements for hardware designers, Test, QA and Service professionals.



Item #
TN01U

\$129.00

Triple Output DC Bench Power Supplies

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1 fixed output @ 5VDC@3A
- Stepped Current: 30mA +/- 1mA



Item #:	Price 1-4	Price 5+
CSI3003X3 0-30Vx2@3A	\$198.00	\$193.00
CSI3005XIII 0-30Vx2@5A	\$259.00	\$244.00



BlackJack SolderWerks



Premium Line Up for Soldering, Repair & Rework

Rugged design at an affordable price..BlackJack SolderWerks from Circuit Specialists Inc. is the industry cost/performance leader and continues our reputation of providing high value products to our customers.

Premium All-In-One Repairing Solder System **BK6000**

The BlackJack SolderWerks BK6000 Repairing System is a digital multipurpose reworking system that incorporates a Hot-Air Gun, Soldering Iron, (compatible with leaded solder or lead free solder), with integrated smoke absorber and a desoldering Gun.

\$249.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack



BK4000 *Thermostatically controlled desoldering station*

The BlackJack SolderWerks BK4000 is a thermostatically controlled desoldering station that provides low cost and solid performance to fit the needs of the hobbyist and light duty user. Comes with a lightweight desoldering gun.

\$149.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack



Hot Air with Vacuum I.C. handler & Mechanical Arm

BK4050

The BlackJack SolderWerks BK4050 is designed to easily repair surface mount devices. Its digital display & tactile buttons allows easy operation & adjustments. The BK4050 includes a hot air gun and a vacuum style I.C. handler.

\$169.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack



BK5000

Hot Air System w Soldering Iron & Mechanical Arm

The BK5000 from BlackJack SolderWerks provides a very convenient combination of hot air & soldering in one compact package. The hot air gun is equipped with a hot air protection system providing system cool down & overheat protection.

\$159.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack



Compact Soldering Station

BK2000

The BlackJack SolderWerks BK2000 is a compact unit that provides reliable soldering performance with a very low price. Similar units from other manufacturers can cost twice as much. A wide range of replacement tips are available.

\$44.95

Complete Technical Details at:
www.circuitspecialists.com/blackjack



BK3000LF

Digital Display Solder Station for Lead Free Solder

The BK3000LF is a compact unit designed to be used with lead free solder that provides reliable performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

\$88.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack



Compact Digital Display Solder Station **BK2000+**

The BK2000+ is a compact unit that provides reliable soldering performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

\$59.95

Complete Technical Details at:
www.circuitspecialists.com/blackjack



Limited Time Offer Free 'BK486'

Fume Extractor with ANY BlackJack SolderWerks Station Purchase.

Bench-Top ESD Safe Smoke Absorber BK486



Quietly and quickly removes fumes and smoke away from the work area providing a safer work environment. The changeable carbon-activated filter helps eliminate noxious fumes. Made of ESD safe material and comes with two filters.

\$27.99

www.circuitspecialists.com/blackjack

How are they using the Propeller chip?

With eight 32-bit processors in one chip and deterministic control over the entire system, the Propeller microcontroller is just plain inspiring. Witness the fascinating array of Propeller-based projects from the winners of our 2008 Propeller Design contest.

1st Place: OpenStomp™ Coyote-1 - A user programmable/configurable open source audio effects processor designed primarily for guitar players. Capable of producing Echo, Distortion, Tremolo, Chorus, and Pitch Dive effects, and can be extended to produce other audio effects through the creation of custom "effect modules."



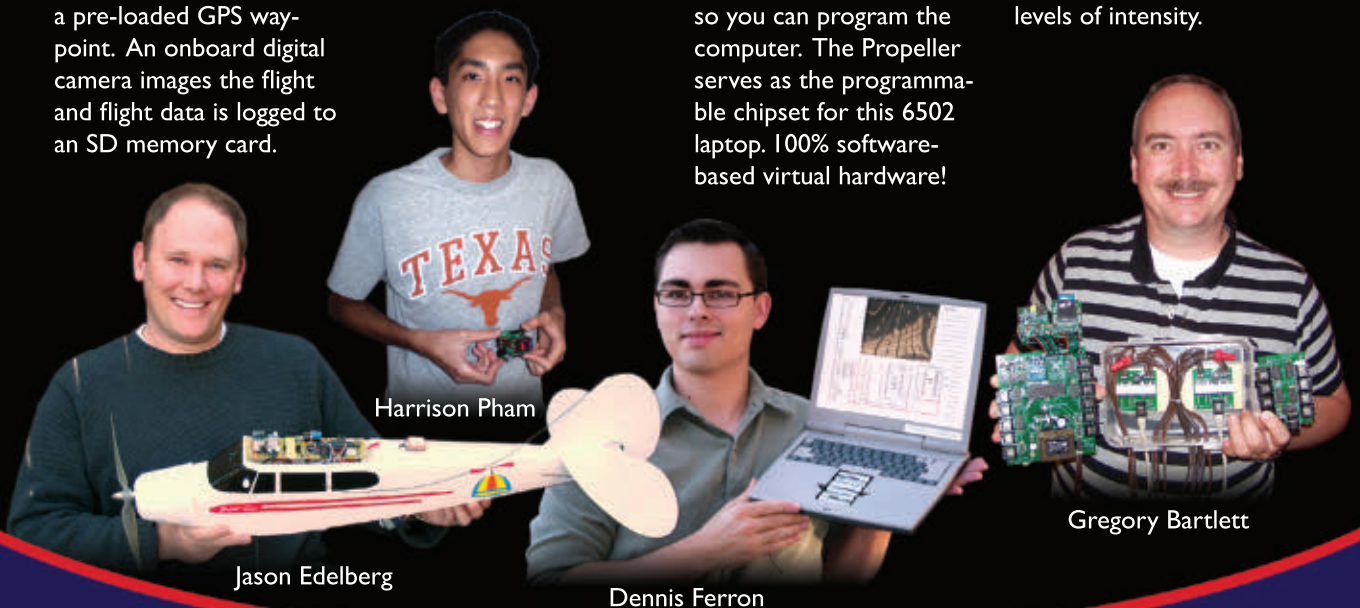
Eric Moyer

2nd Place: OughtTo-Pilot - UAV application. The Propeller-based system senses and controls the RC aircraft's attitude to maintain level flight and guides the aircraft toward a pre-loaded GPS way-point. An onboard digital camera images the flight and flight data is logged to an SD memory card.

3rd Place: PropIRC - Internet Relay Chat application. Implements a minimal client that directly connects to remote IRC servers via a standard Ethernet connection.

HM: PROP-6502 Laptop - A laptop with a 6502 co-processor and 64K of static RAM. The Propeller handles all I/O for the 6502 and runs an integrated debugger so you can program the computer. The Propeller serves as the programmable chipset for this 6502 laptop. 100% software-based virtual hardware!

HM: Prop 128 Light Controller - A light controller with a main board and daughter boards that can synchronize up to 128 light channels to music. Each light channel has 255 levels of intensity.



Jason Edelberg

Harrison Pham

Dennis Ferron

Gregory Bartlett

To read all about the **Propeller Design Contest** visit www.parallax.com/tabid/720/Default.aspx. To place an order call our Sales Department toll-free at 888-512-1024 (Mon-Fri, 7 a.m. - 5 p.m., PDT).

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